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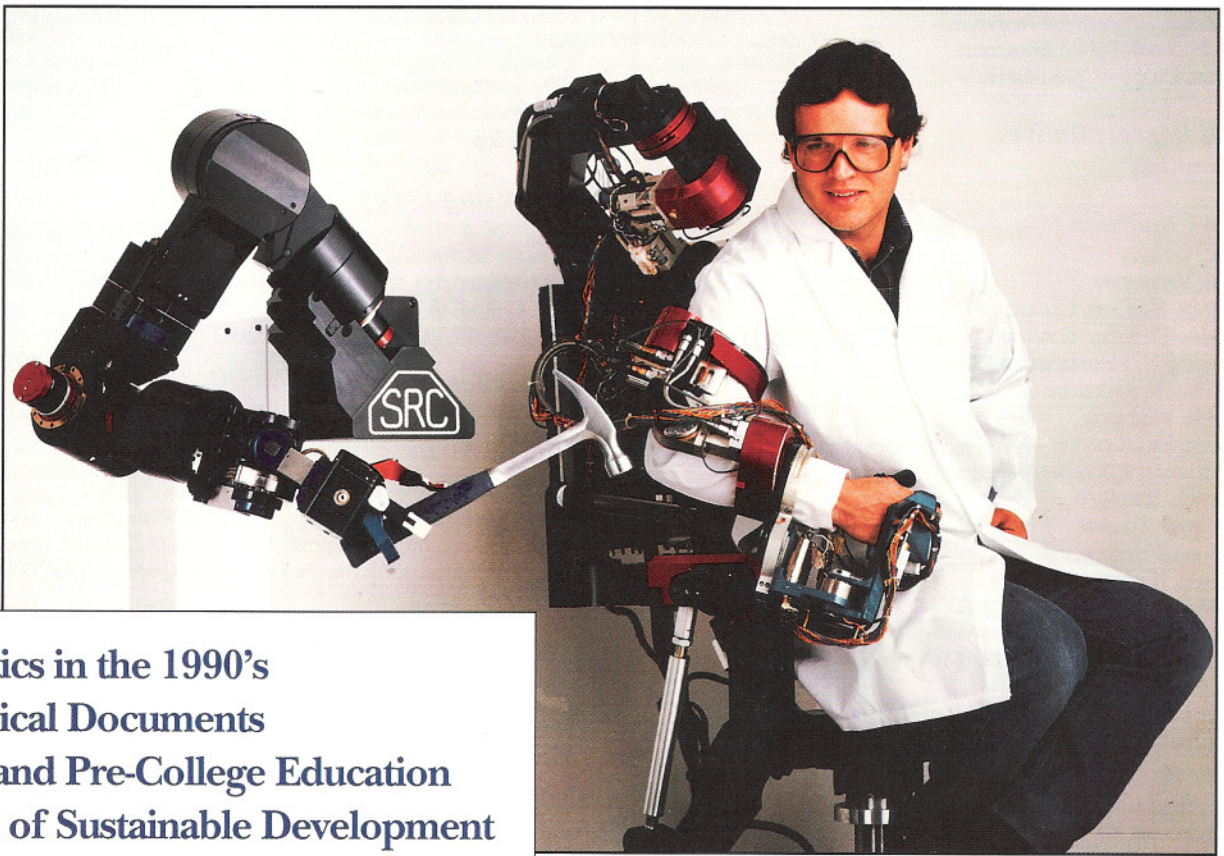
# IEEE Canadian Review




Robotics in the 1990's
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IEEE and Pre-College Education
Facets of Sustainable Development
Global R&D and Competitiveness

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# *IEEE Canadian Review General Information*

The *IEEE Canadian Review* is published three times per year - Spring, Fall and Winter. 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.

In this context, the *IEEE Canadian Review* serves as a forum to express views on issues of broad interest to its targeted audience. These issues, while not necessarily technologically-oriented, are chosen on the basis of their anticipated impact on engineers, their profession, the academic, business and industrial community, or society in general.

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

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***- The Managing Editor***


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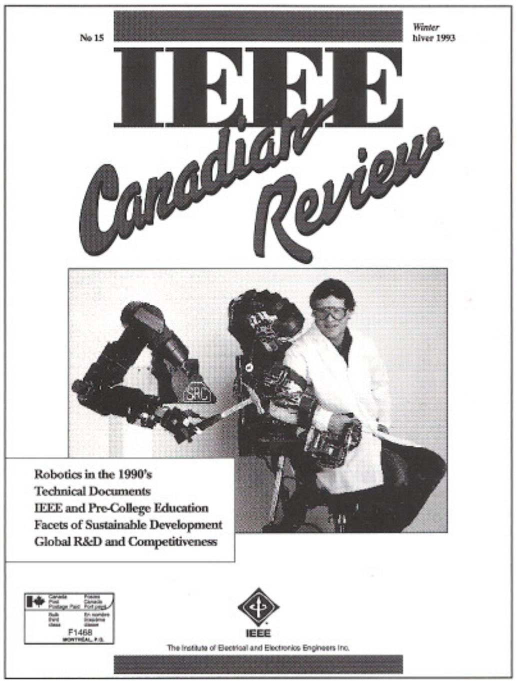
**Cover picture**

Our cover picture shows a Sarcos Dextrous Arm Teleoperation System being supplied to Hydro-Québec by Sarcos Research Corporation of Salt Lake City, Utah. It is comprised of a fully force reflective, exoskeletal master that commands a high capacity anthropomorphic Slave robot arm. The Slave is kinematically equivalent to a human arm with 10 degrees of freedom (DOF), which includes a patented 3 DOF end effector (hand) designed to handle human tools and other objects with a high level of dexterity. Forces felt by the Slave are transmitted back to the operator via the powered Master at user-specified force reflection ratios. The arm has a payload capability of over 100 lbs everywhere in the workspace. (*Photo by Ed Rosenberger, courtesy of Sarcos Research Corporation*)

**Tableau couverture**

En page couverture se trouve la photo du télémanipulateur "Dextrous Arm Teleoperation System" de SARCOS Research Corporation, Salt Lake City, Utah, vendu à Hydro-Québec. Les gestes de l'opérateur, qui servent à commander le bras esclave anthropomorphique, sont captés par l'exosquelette du maître intégrant un retour d'effort dont l'échelle est contrôlable. Le modèle cinématique de l'esclave suit celui du bras humain et comprend dix degrés de liberté, dont trois relèvent de l'organe terminal (main). Celui-ci est conçu pour la manipulation d'outils et d'objets non-spécialisés d'un poids allant jusqu'à 100 livres (45 kg). *(Photographie de Ed Rosenberger, courtoisie de Sarcos Research Corporation.)*

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# The Management and Finance of our Region

### *Election Results*

Dr. **Raymond Findlay** of McMaster University has been elected Director-Elect for 1993 and will become our Director in 1994 for a two-year term. Elected for a two-year term as the Director of Division IV is Dr. **Kenneth Dawson** of TRIUMF in Vancouver, B.C. Dr. **Wallace S. Read** was elected by the IEEE Assembly as IEEE Vice President-Standards Activities. Our congratulations to all of them.

### *Appointments*

The following new appointments have been made to the Region Executive Committee: **Bill Kennedy** – Secretary, **Timothy Chia** – Student Activities Committee (SAC) Chair, **Mike Boudreau** – WCC Chair, **Hussein Mouftah** – CCC Chair and **Ken Butt** – ECC Chair.

Appointed to the Region Committee are: **Pierre Allard** – Membership Development, **Fiorenza Albert-Howard** – Public Awareness, **Robert Burridge** — Educational Activities.

A complete slate of Region Committee Members appears on the inside front cover. Should you need to obtain anyone's address and phone number, please contact your Section Chair.

### *Region 7 Committee Meetings*

We had very well attended Council and Region 7 meetings last Fall, in Toronto. These provided an opportunity for Section Chairs and other committee members to interact, share ideas and address problems. The delegates were pleased by the visit of many outstanding guests from outside R7, led by President **Martha Sloan**. Some items of importance from the meeting are as follows:

1. The Forward Planning Committee, Chaired by Junior Past Director **Tony Eastham**, presented an interim report addressing the concern of your Director that Region 7 may be drifting away from "what an IEEE Region is supposed to be doing." It also presented short term and long term objectives of Region 7.

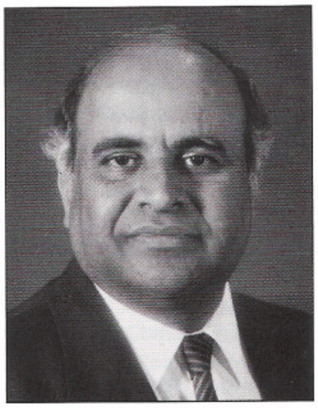
2. A Motion by Tony Eastham – *that whereas the R7 Executive Committee has agreed in principle (pending detailed planning and consultation with membership) to the amalgamation of IEEE Region 7 and the Canadian Society for Electrical and Computer Engineering (CSECE), The Regional Committee endorses this proposal and authorizes the "Blue Ribbon Committee" to enter into discussions with the parent organizations (IEEE and the Engineering Institute of Canada) and to prepare a detailed financial and operational plan for review and consideration by the R7 Executive and Regional Committees in the Spring of 1993* – was carried.

3. Your Director was instructed to approach the relevant IEEE entities to request that the IEEE Canadian Review be offered as part of the All Periodicals Package.

4. The newly appointed Section/Chapter Support Chair identified four chapter formation activities and eight potential new chapter formations in Region 7.

5. Three Council Silver Medals and the McNaughton Medal were awarded.

*by Dr. Vijay K. Bhargava*
*Director, IEEE Canada*



### *Finance*

The region derives its income from two main sources, the region rebate and the region assessment.

The rebate is used to administer IEEE affairs within the Region. In our case, US $ 52,000 along with the exchange and interest, is almost sufficient to organize our training and business meetings.

The assessment is used to support the IEEE Canadian Review, the Region office and other special projects. Last year, the three issues of the Review cost us about $ 75,000 (excluding the tremendous efforts of our volunteer Managing Editor – Professor Ted Wildi). When the review was launched, we were told that it would only cost $1 per issue per member. Within four years the cost has doubled.

In 1992, the cost of operating the Region 7 office was about $95,000. We pride ourselves in the fact that we are the only region in IEEE to have an office. Given the price tag is it worth it? If you look at the back of your membership card, it gives us a toll-free number and other instructions to get in touch with the IEEE. To be sure, a very small number of our members and volunteers find the Region 7 office to be useful. But is it fair to "tax" the entire membership to provide revenues to run this office?

This year, Regions 8 and 9 will get "special desks" in the IEEE Service Centre. Region 10 will be home to an IEEE Asia Pacific Service Centre, and only a small part of its revenue will come from assessment paid by R10 members. For Regions 1 to 7 there is the toll-free number. If we are not satisfied by the services provided by the IEEE Service Centre, the answer is not to increase the assessment of our members to provide funds for our own "Canadian Mini Service Centre", but to exhort the IEEE for better services. This is the approach that I have taken as your Director.

I would very much like to hear your opinion on the issues raised in this article or any other IEEE-related concerns that you may have. I can be reached c/o Department of Electrical and Computer Engineering, University of Victoria, P.O. Box 3055, Victoria, B.C., V8W 3P6; Telephone: (604) 721-8617; Fax: (604) 721-6048; e-mail: V. bhargava @ ieee · org.

# Robotics in the 1990's

## *An overview of current trends*

*by Paul Freedman*
*Centre de recherche informatique de Montréal*

*In the 1990s, robots are leaving the factory floor to work in new areas such as the resource industries, the subsea and in space. Unlike industrial automation where the robot works in "its own" world, these environments are not structured, are sometimes dynamic, and cannot be completely modelled. It therefore becomes imperative to have a human operator present who can guide, rather than control the robot, using a computer-assisted interface. Work in this area of cooperative robot/operator interaction is called telerobotics, and the application to intervention environments is the focus of this article.*

*Dans les années 1990, les robots quittent les ateliers pour travailler dans de nouveaux domaines tels les industries primaires, l'univers sous-marin, et l'espace. Au contraire du contexte manufacturier dans lequel le robot travaille dans "son monde", ces environnements ne sont pas structurés, sont souvent dynamiques, et ne peuvent pas être modélisés complètement. Par conséquent, il est impératif d'avoir un opérateur humain qui donne des directives au robot plutôt que de le commander. Cette nouvelle façon de travailler, en faisant coopérer robot et opérateur à travers une interface informatisée, est appelé la télérobotique; son application aux domaines d'intervention constitue le thème principal de cet article.*

What exactly is robotics? A layperson might suggest that it is "the computerized control of mechanical systems". The word 'robot' itself comes to us from the Czech word 'robota' meaning 'worker', drawn from Karel Capek's 1922 play, "Rossum's Universal Robots".

More precisely, a robot in the 1990s is better defined as a machine which:

1) works in contact with its environment; for example, a manipulator arm which performs "pick and place" motions, or a motorized platform which navigates from place to place;

2) is programmable;

3) behaves in an "intelligent" way, i.e. the robot senses and reacts to changes in its environment.

Note that this very general definition combines perception, planning, and action, the three commonly identified axes of modern robotics.

Robotics as we know it today is a post World War II science and technology. In 1953, research at MIT led to the development of numerical machine technology for performing and memorizing precise and repeatable motions. In 1958, the Planet Corporation (U.S.A.) successfully combined this technology with the tele-manipulator technology developed for the American nuclear industry to create the first industrial robot manipulator arm. Soon after, Unimation (U.S.A.) was born and the first "Unimate" was delivered to General Motors in 1961. In this way, the programmable automation of the automotive industry, together with the master/slave tele-manipulators of the nuclear industry, established the technology of modern robotics. Concurrently, academic research in the areas of cybernetics and artificial intelligence helped define the new science.

In 1968, Unimation licensed its robot technology to Kawasaki and since then, Japanese companies have come to dominate industrial robotics around the world. Today, Unimation is no more and there are only two manufacturers of robot manipulators remaining in North America: Adept in the United States and CRS Plus in Canada.

But even as progress continued, in what came to be called "factory automation" or "flexible manufacturing", robotic developments were taking place elsewhere. For example, the Soviet Union successfully landed and tele-operated a mobile robot on the Moon in 1971. In 1976, NASA's Viking I landed on Mars equipped with a folding manipulator arm which was tele-operated from Earth to obtain soil and rock samples. In 1980, SPAR developed the "Remote Manipulator System" known more widely as the "Canadarm" for tele-manipulation tasks onboard the NASA space shuttles.

While factory automation and industrial robotics is now relatively mature, the emerging field of *intervention* robotics poses new technical and scientific challenges (see Table 1). In the resource industries such as forestry and mining, in undersea operations and in space, the work environment is only partially known, has little structure, and may not be static. As a consequence, robot actions must be sensor-based, i.e. the execution of an action must be self-monitored, so that if the circumstances change, the action can be suspended/aborted or otherwise changed. Moreover, uncertainty in the world limits the extent to which robot actions can be pre-specified. It therefore becomes imperative in certain contexts to have a human operator present who can *guide* or *supervise*, rather than control, the robot, using a computer-assisted interface. Clearly, such cooperation places special importance on the robot's sensing and reasoning capacities because the operator is often located at some remote site. This is especially true for tasks under water, in space, and in the cleanup of nuclear waste. Work in this area of cooperative robot/operator interaction is called *telerobotics*, and the application to intervention environments has become the new focus of robotics in the 1990's.

| | industrial robotics | intervention robotics |
|---|---|---|
| ***Environment*** | | |
| structured | yes | no |
| modelling | much detail | little detail |
| ***Task*** | | |
| pre-defined | yes | not always |
| repetitive | typically | rarely |

Table 1. Comparing industrial and intervention robotics

## *Elements of robotics*

In Figure 1, we present the architecture of a modern robot control system. At the lowest level, actuators cause the articulations (joints) of a robot arm to rotate or extend/retract by a certain amount, or cause the wheels of a robot platform to turn. Internal sensors, typically optical encoders, provide the necessary feedback to obtain closed loop control. This latter architecture constitutes the so-called "first generation" robots.

Each independent articulation is called a "degree of freedom" (dof). Most robot manipulators have at least four dof's in order to provide independent control in position and orientation in three dimensions. A manipulator with more than six dof's (such as the Canadarm) can be controlled to obtain robot motions that are optimal with respect to a given performance criteria. By way of analogy, the human arm provides seven dof's and most human arm motions serve to minimize the total arm energy.

Most industrial robots have electric actuators which are best suited for the rapid manipulation of relatively lightweight objects such as are found in the manufacture of consumer electronics. In flammable environments, pneumatic actuators are often preferred but offer poorer performance. Hydraulic actuators have long been used for manipulating heavy objects but more recently, new technology is making hydraulics appealing, even for high speed manipulation of lightweight objects and for anthropomorphic tele-manipulators.

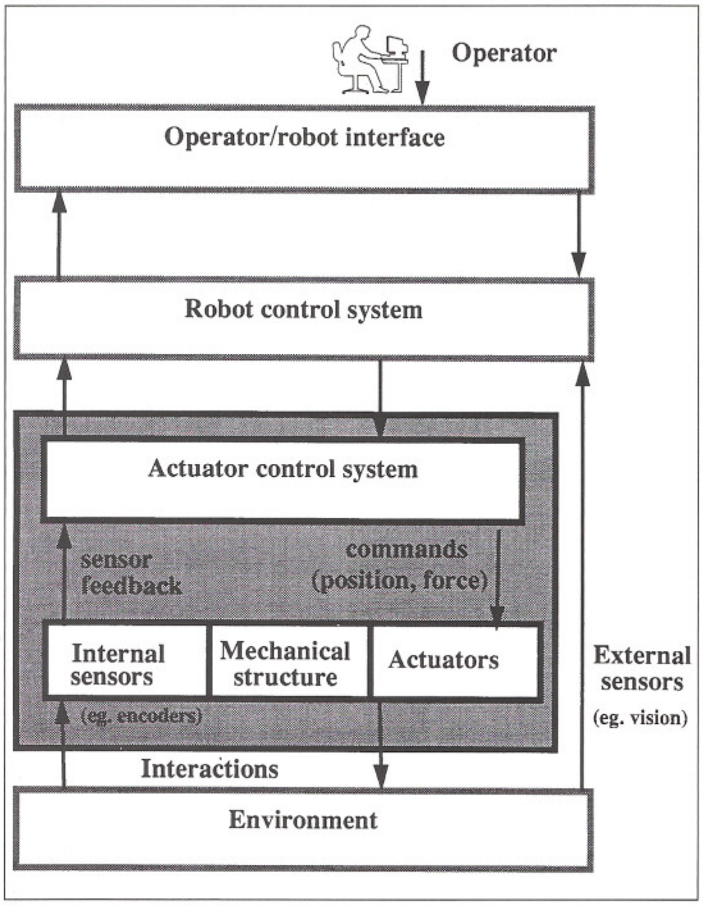



Figure 1. An advanced robot architecture.

"Second" and "third" generation robots are characterized by an additional architectural layer. Here information coming from external sensors is used to alter the commands sent to the actuators so that the robot behaves in a more intelligent way. Thus, it avoids collisions, only reaches for a part when there is part to pick up, and so forth. Whereas the external sensors of second generation robots were largely binary (eg object is present/absent), those of third generation robots are more complex and involve computer vision systems and force/torque sensors.

Finally, as Figure 1 shows, there is an operator/robot interface with some kind of input device. In its simplest form, this might be a joystick or a keyboard plus monitor, for specifying robot actions. Traditional master/slave tele-manipulation (as developed by the nuclear industry) requires an input device which duplicates in a scaled-down fashion the structure of the robot arm. In this way, the operator has direct control over the motion of each of the robot articulations. In contrast, computerized interfaces offer "resolved motion rate control", whereby the displacement of a "hand controller" determines the direction of the motion of the robot end effector (gripper or tool), instead of the motion of a particular articulation. The amount of displacement determines the speed of the robot motion, hence the name "rate" control. Force reflection is often available, to permit the operator to sense and control the forces at the end effector, rather than its position. In the context of telerobotics, the operator/robot interface may provide extra operational sophistication such as:

a) the possibility of finer control over actuator motions

– by removing noise in the operator gestures

– by selectively locking certain articulations so that the robot motions are more carefully constrained

– by introducing artificial 'gearing' so that a large change in the operator input gives rise to a small change in the robot motion.

b) the possibility of 'transforming' the operator input so as to obtain improved robot motions which are optimal with respect to time, energy, etc.

c) the possibility of storing the operator input and resulting robot motions in order to improve the performance of the operator and the robot

d) the possibility of re-directing the operator input to a simulator for training purposes

The key to any advanced control are mathematical models describing: (1) the robot structure, (the number of articulations, how they are connected, etc.) which define the *kinematics* ; and (2) the robot behavior (inertia, effects of varying payload, actuator performance, etc.) which define the *dynamics*. For this reason, some of the most important research in telerobotics concerns how to define such models and estimate their parameters.

## New Developments

Developments in intervention robotics are taking place in many countries around the world. We shall briefly describe some of the newest ones, first on the international scene, and then in Canada.

### International scene

France has become a recognized leader in intervention robotics, thanks in part to the research at the Commissariat à l'énergie atomique (CEA) in the area of computerized master/slave manipulation for the nuclear industry. Elsewhere in France, the LAAS (Laboratoire d'automatique et d'analyse de systèmes) of the Centre national de recherches scientifiques (CNRS) has

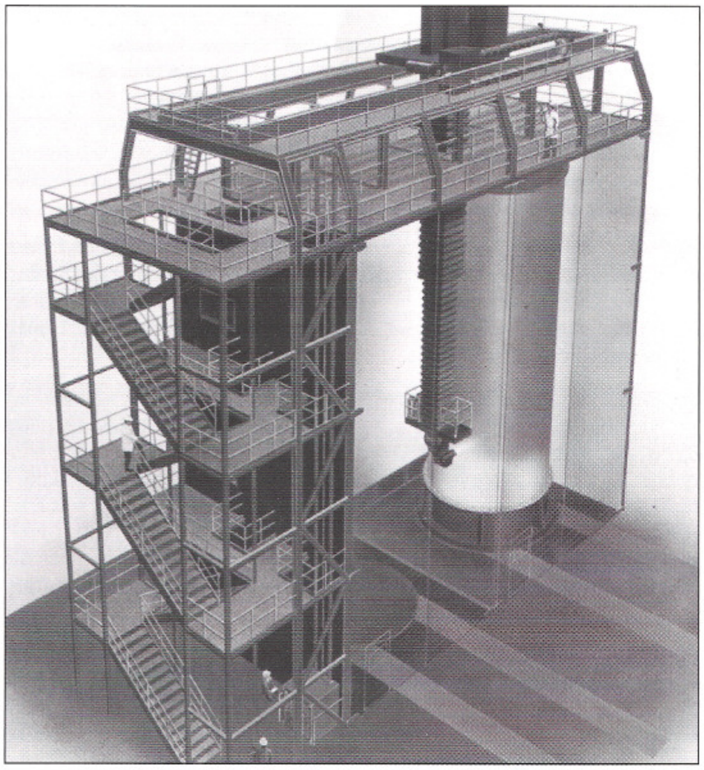


Figure 2. The Advanced Solid Rocket Motor facility that NASA will use to refurbish post flight space shuttle rocket motors, will employ a series of three robots supplied by **Vadeko Inc.** of Mississauga. The picture above shows one of the robots painting the exterior of the rocket motor segment. The robot can travel between the two bays shown, and will include the rotation of the rocket motor as one of its degrees of freedom. The other two robots will clean, inspect, and re-line the motor interior. All robot trajectories are derived using off-line programming techniques. Inspection data about the motor is relayed back to facility mainframes for archiving.

been a leading centre for autonomous mobile robotics research since 1979, and some of this work led to the development of autonomous mobile robots for cleaning subway stations in Paris. LAAS is also a major player in the French national program RISP (groupement Robots d'intervention sur site planétaire) to develop a tele-programmable semi-autonomous rover for Mars exploration.

At the European level, two examples of major initiatives are AMR (Advanced Mobile Robot) and Panorama. The focus of the AMR project is the advanced tele-operation for assisting in disaster relief after a fire, earthquake, or nuclear accident. Two mobile robots are under development: a small one equipped with a manipulator and advanced sensing for exploration, and a large one for transport to/from the disaster site. Here the research emphasis is on advanced operator/robot interfacing and autonomous navigation.

The focus of the Panorama project is autonomous navigation in intervention (terrestrial) environments. Three testbeds are under development, for research into operator/robot interfacing, path modelling/planning, and sensing/control for navigation in rough terrain.

In the United States, NASA's **Jet Propulsion Laboratory** (JPL) has also conducted much research into tele-operated manipulation and more recently, coordinated tele-operation of multiple manipulators and autonomous mobile robots for planetary exploration.

On the commercial scene, **Sarcos Research Corporation** (Salt Lake City, Utah) is developing anthropomorphic master/slave manipulators based on new generation hydraulics. (The cover picture shows such a manipulator in action). **Kraft TeleRobotics** (Kansas, Missouri) and **Schilling Development Incorporated** (Davis, California) are developing telerobotic technology for nuclear waste cleanup. Elsewhere, TRC has developed an advanced mobile robot for automated transport in a hospital environment which is now undergoing clinical trials. **Remotec** (Oak Ridge, Tennessee) is one of the leaders in tele-operated mobile robot platforms equipped with closed circuit television mounted on a pan/tilt platform, for intervention in hazardous environments.

### *Canadian scene*

Canadian companies were among the first to develop robotic products for intervention tasks, in response to the demands of the subsea and nuclear industries. For example, in the late 1960s, a company called International Hydrodynamics developed and successfully marketed a manned submersible.

In 1974, **International Submarine Engineering** (ISE) of Port Coquitlam, B.C., was created to develop remotely operated vehicles. Responding to the needs of the subsea industry, hydraulic manipulators were developed, along with force reflection. ISE is currently selling such telerobotic manipulator systems to the US Air Force and the US Department of Energy. An ISE manipulator was also used to decommission Reactor No. 2 after the nuclear accident at Three Mile Island. ISE is currently developing even more sophistication, such as collision detection and avoidance, for their new generation of autonomous vehicles for long range underwater mapping.

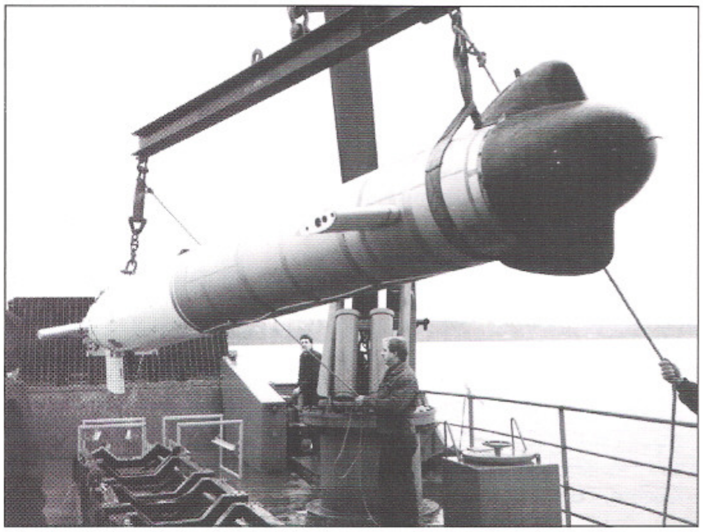


Figure 3. ISE ARCs Autonomous Underwater Vehicle being launched from the ISE boat "Researcher". Typical applications include under-ice hydrographic survey and oceanographic sensing. (*ISE*)

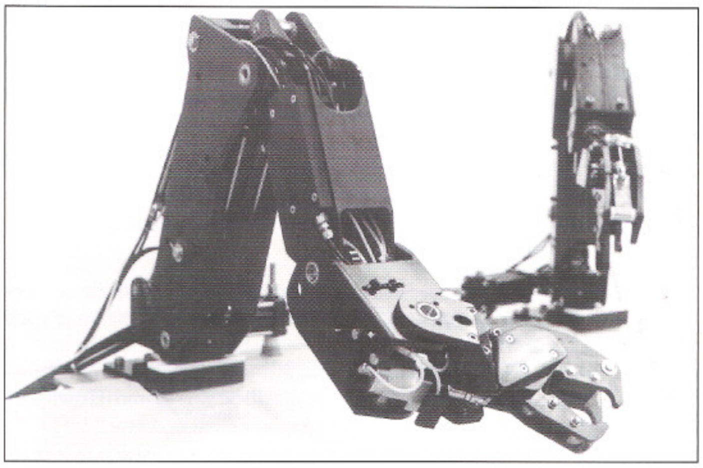


Figure 4. ISE Robotic Manipulator. Typical applications include nuclear decommissioning, welding, aircraft servicing and maintenance, subsea cable repair, and offshore oil drill rig support. (*ISE*)

Another west coast company, **RSI Research** (Sydney, B.C.) specializes in the development of manipulator arms, hand controllers, and advanced telerobotic control systems. Technology and equipment supplied by RSI Research was used in the recovery of components of the space shuttle Challenger.

For the last ten years, **Vadeko** (Mississauga, Ontario), has been developing large-scale manipulator robotic systems. For example, a current NASA-funded project involves the development of three 5-dof manipulator systems for building and refurbishing casings for the solid rocket motors of the NASA shuttles. Vadeko's strengths are in the areas of large mechanical structures, graphical simulation, and systems integration. Elsewhere in Ontario, **Cyberworks** (Orillia, Ontario) has developed a line of autonomous mobile robots called "CyberVac" for industrial vacuuming. **Pedsco** (Scarborough, Ontario) has been active for more than fifteen years in the area of tele-operated mobile robot platforms for hazardous applications such as bomb disposal.

In the mining industry, companies such as **Black Box Controls** (Glenn Williams, Ontario), ISE, and INCO (Sudbury, Ontario) were involved in the development of tele-operated underground mining vehicles such as scoop trams. INCO recently demonstrated such control from the mine surface, with an operator interface consisting of a TV monitor, two joysticks, and auditory feedback to provide some indication of how hard the vehicle was working. **Noranda,** in cooperation with **École Polytechnique** (Montréal, Québec), has developed a ceiling-mounted optical guidance system to automatically guide scoop trams along pre-defined paths.

In the forestry sector, the **University of British Columbia** has been working closely with MacMillan-Bloedel and RSI Research since 1985 to model and better control heavy hydraulic equipment (construction and forestry machines). They have also compared the performance of different kinds of operator interfaces, to better understand some of the human factors associated with advanced tele-operation.

Telerobotic maintenance of live electrical transmission lines is the primary focus of the robotics research at the **Institut de recherche d'Hydro-Québec** (IREQ). A state-of-the-art testbed is taking shape, thanks in part to a three-year 1M$ collaborative effort which involved **McGill University** and the **Centre de recherche informatique de Montreal** (CRIM) and Hydro-Québec.

TDS (Telerobotics Development System) is a 5-year, 10.5 M$ project about to begin, involving **MPB Technologies,** Hydro-Québec, **Canadian Aviation Electronics** (CAE), and McGill University. Quoting from the PRECARN* 1991 annual report:

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**PRECARN is an acronym for the PRECompetitive Applied Research Network, a Canada-wide industrial consortium of some 35 companies to promote precompetitive research and development in intelligent systems.*

"Three different telerobotic systems of different scale and precision will be developed: a micro-robot with sufficient precision to manipulate a single cell, a macro-robot capable of working on overhead electrical transmission lines, and a research robot for medium-sized applications of high precision."

ARK (Autonomous Robot for a Known environment) is a 4-year, 7.1 M$ project which began in 1991, involving Ontario Hydro, Atomic Energy of Canada (AECL), the **National Research Council of Canada**, the **University of Toronto,** and **York University.** Again quoting from the PRECARN 1991 annual report:

"The ARK project will produce a self-contained mobile robot with capabilities specifically designed for operation in an industrial setting – the large shop floor at AECL CANDU in Mississauga. Using its onboard sensor system consisting of sonars [ultrasound], cameras, a dead reckoning system [odometry] and a laser ranger finder, the robot will be able to find its own way from one place to another, with no help from a human operator."

Part of ARK's success will be due to the strengths of the National Research Council of Canada's **Institute for Information Technology** robotics group, which is working in the areas of computer vision (especially laser range finder technology), autonomous mobile robots, and telerobotic manipulation.

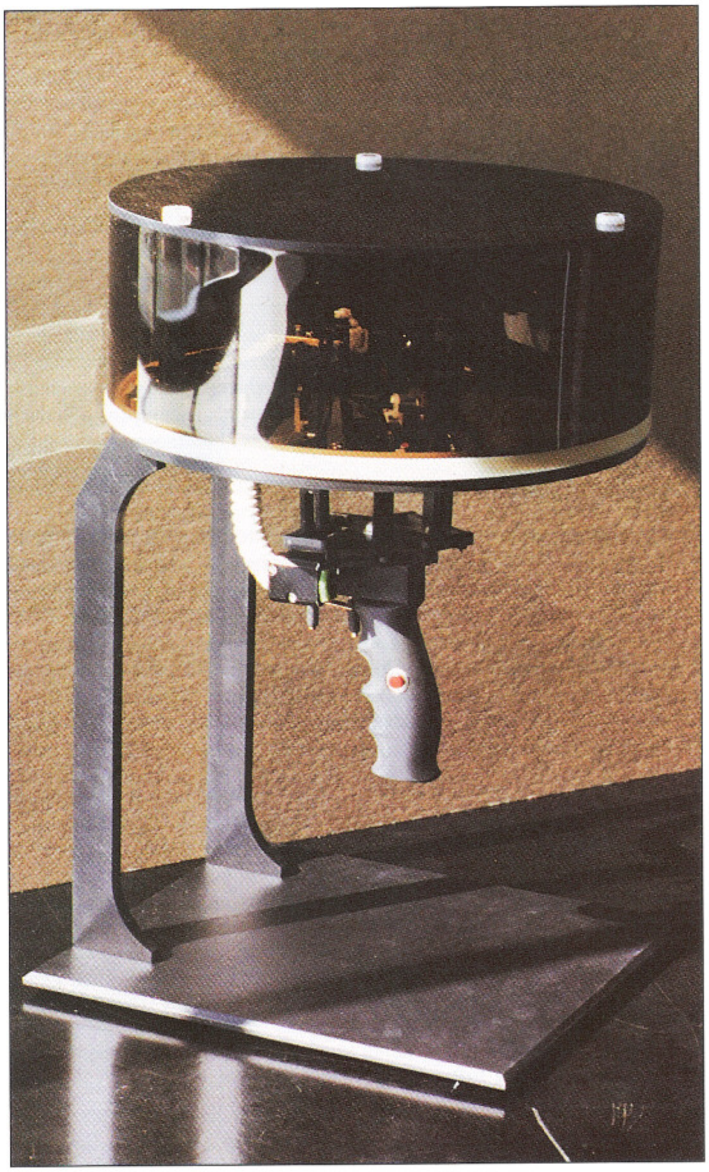

Figure 5. This 6 degree-of-freedom hand controller uses a joystick which allows the operator to concentrate on the end tool effector of a slave system without regard to intermediate linkages. The controller accepts direct responsive inputs from the operator which are computer interpreted and communicated to and from the remote system with precise feedback control translation. The controller permits an X,Y,Z range of ±75 mm, together with a roll/ pitch/ yaw range of ± 30°, all to an accuracy of ±1 %. (*RSI Research Ltd.*)

Both TDS and ARK are PRECARN projects, with funding from provincial and federal governments. PRECARN is also managing the **Institute for Robotics and Intelligent Systems** (IRIS), one of the federal Networks of Centres of Excellence. Over 100 academic researchers from 19 Canadian universities are participating in 22 projects in the areas of computational perception, knowledge-based systems, and intelligent robotics. Funding of some 23 M$ began in 1990 and will run over 4 years. Among the leading university groups active in IRIS (and therefore in robotics) are the **McGill Research Centre for Intelligent Machines** (McRCIM), the **Computer Vision and Digital Systems Laboratory** at Laval University, and the **Laboratory for Robotics and Telerobotics** at the University of British Columbia. It is hoped that some of the IRIS-sponsored work will become PRECARN precompetitive research and development.

Finally, much space-related robotics research in Canada is funded by the technology development program of the Canadian Space Agency called STEAR (Strategic Technologies in Automation and Robotics). While SPAR Aerospace (Toronto, Ontario) is the prime contractor for NASA-related work such as the Canadarm, STEAR was established in 1988 to encourage and support research by other companies in advanced telerobotics for the Canadian Space Station Program's Mobile Servicing Station (MSS) and its Special Purpose Dextrous Manipulator (SPDM).

Total funding for STEAR until the year 2000 is about 75 M$; annual funding is about 3 M$ to support the work of approximately ten companies and a half dozen universities across Canada.

## *Additional reading*

In the academic and scientific community, most of the new work is presented at the annual **IEEE International Conference on Robotics and Automation.** Other conferences, such as the annual **International Symposium on Industrial Robotics** (ISIR) and the **International Workshop on Intelligent Robots and Systems** (IROS), co-sponsored by the IEEE and the **Robotics Society of Japan,** concentrate respectively on developments in industrial robotics and on the applications of new robotic technology.

## *Conclusion*

In the 1990's, robots are leaving the factory floor to work in the resource industries, subsea and in space. In order to cope with the lack of structure and uncertainty in such environments, a human operator must typically be present to guide, rather than control, the robot using a computer-assisted interface.

In this article, we presented a working definition for such robots and described some of their important elements with an emphasis on cooperative robot/operator interaction now called 'telerobotics'.

Finally, we examined some of the major projects and players on the international and Canadian scenes.


## *About the author*

**Paul Freedman** obtained his B.A.Sc., University of Toronto (1978); his M.A.Sc. (Electrical Engineering), University of British Columbia (1983); and his Ph.D. (Electrical Engineering), McGill University (1988). Dr. Freedman is Lead Researcher in the group Computerized Control of Industrial Processes and Computer Vision at the Centre de recherche informatique de Montréal (CRIM). He is also an adjunct professor in the Department of Electrical Engineering at McGill University, and a member of the Ordre des ingénieurs du Québec. Prior to joining CRIM in 1991, he conducted postdoctoral research in robotics at the Laboratoire d'automatique et d'analyse des systèmes (LAAS) du CNRS in Toulouse, France.

# Technical Documents

## *An essential supplement to hardware*

*by Terry D. McMullen*
*Toronto, Ontario*

*Technical documentation has often been considered a necessary evil from which most people shy away. The emergence of electronic consumer products like the personal computer, has triggered a corresponding need for Technical Writers who, while encompassing solid technical concepts, can produce documentation that is easily read and understood. Technical documentation, as a collective term for such items as User's Guides, Text Books and Training Manuals, supports any product, by communicating the necessary information to ensure the product's safe, and efficient operation.*

*La documentation a souvent été considérée comme un mal nécessaire que la plupart des gens fuient. L'avènement de produits tels que l'ordinateur personnel a déclenché un besoin plus grand d'écrivains techniques qui peuvent produire une documentation facilement lisible et compréhensible, tout en incluant de solides concepts techniques. La documentation technique comprend les guides de l'usager, les manuels d'entretien et les manuels de référence Elle supporte n'importe quel produit en communiquant l'information nécessaire à son utilisation sécuritaire et efficace.*

A **technical document** can be defined as a document, conceived, written, and edited by someone who has special technical skills, discussing a product for which a user will require special instructions.

Non-technical documentation could encompass procedural documentation; for example, a banking procedural manual for filling out loan applications. Such writing requires little in the way of expert knowledge in finance or economics; the simple ability to present clear and precise instructions is sufficient.

Once a document is seen to be a Technical Document, the decision of "Who writes technical documentation?" must be made. This is not a difficult question to answer, if you have had years of experience in producing documentation. Technical documentation *must* be written by a Technical Writer. Technical writers are usually graduates of a technical college, with the skill and desire to be a writer. They are often more skilled at putting together readable and useable documentation, than engineers or other professionals.

Technical writers become directly involved with the product they are describing. This produces important side effects. In effect, experience shows that product designers sometimes tend to overlook useability flaws in their product. Technical writers, by having to become "instant users", become skilled at identifying such product idiosyncrasies that users will have difficulty with. Their skill at writing in order to circumvent these difficulties will ensure that the technical document - and the product - will be a success.

Users of modern consumer products look for documentation that is useable, non-intimidating, and complete. Anyone required to produce documentation for the first time, can simplify potential headaches, and reduce confusion, by performing two activities: identifying the audience for the document, and planning the document's content.

### *Determining Your Audience*

An audience, the people who will read and use your document, is an entity that can be identified as having a specific objective to achieve with your document. Typical audiences may include professional people, such as engineers, doctors, and scientists; skilled individuals, such as service and support personnel; and relatively unskilled individuals, such as product users who may not have had previous experience with similar types of products.

The writing style and the language used can vary greatly with the audience that is being addressed. A non-technical (or non-skilled) audience is sometimes best served by using simple language and a short sentence structure. On the other hand, a highly skilled technical/professional audience will usually require a more sophisticated approach.

Identifying a document's audience is the key to developing a successful technical document. In many cases, more than one audience can be identified, and the document has to be designed to meet the needs of those audiences. At no time, however, should more than three different audiences be addressed in a single document. Whenever four or more audiences are identified, the single document should be re-designed into two, or perhaps even three separate documents. A typical 3-audience document would be a standard military-grade User's Manual. This type of document is usually divided into six chapters.

- Chapter 1 identifies the equipment being covered, and provides maximum and minimum operation conditions. Additionally, it will contain information that is specific to what is known as $C^3$ personnel (Command, Control and Communications). This audience isn't particularly interested in the technical aspects of the product, but does want to know what the equipment will do, and what other equipment is needed to make it operate correctly.

  In essence, this chapter would be a generalization of what the rest of the manual contains. This information is what a military authority (read upper management in a commercial environment) would want to know.
- Chapter 2 details installation activities that would be performed at a maintenance/installation depot; it only contains installation-related material.
- Chapter 3 contains material on the detailed theory of operation that would generally be used for instruction purposes and as a source of reference during extensive maintenance activities.
- Chapters 4 and 5 are preventive and corrective maintenance instructions that would be required by maintenance personnel only. Others would not have the special knowledge and experience required to perform maintenance tasks.
- Chapter 6 would contain the parts listings and schematic drawings required to support both the installers and the maintainers. This chapter would then have a dual audience while all others have single audiences.

When identifying an audience, you should first speak to your Marketing Department to establish who the product was originally intended for, and who in the final analysis will use it. One critical point to remember is that when identifying the audience, be sure to rely on the input of those responsible for the product's development. They have the product insight necessary to successfully identify the audience.

For example, assume that the marketing department of an electronics manufacturer has been responsible for producing a new computer-based device to emulate a competitor's product at a greatly reduced price. The marketing people, who have access to the actual product user, confirm that the product will be used by experienced operators who are familiar with the operation of the competitor's product and will require nothing more than general instructions on the differences in operation. Consequently, the marketing department, being responsible for the development of this product, is best suited to identify the product's audience.

To successfully identify the audiences for any document, you should analyze three things:

A) What environment will the document be used in, and is this environment different from that in which the product will be used?

In the case of an exhaust-gas oxygen analyzer, the technical documentation may be kept in an engineer's office, while the device itself might be located 150 feet up the side of a blast furnace. Large, bulky documentation that is difficult to handle, let alone read, is definitely not in order. An easily-handled and easily-read reference booklet is more appropriate, while the more sophisticated technical manual can be located in more 'user friendly' surroundings.

B) What will the audience do with the product and documentation? Will the audience be required to perform complex maintenance, repair, or operations tasks, based on the content of the manual?

The answer to these questions will determine the depth of detail to be presented and the manner in which it will be written. If the document must address the complex operation and maintenance of a product, the sheer size of the finished document may dictate that it be split into two volumes: an Operations Manual and a Maintenance Manual. In this way, the Operator is sure to have operating instructions available without handling an awkward binder that, from his point of view, is half-full of irrelevant information.

The Maintainer will probably have the same opinion. Although he may want operation information to verify that a repaired product functions correctly, he doesn't want to flip through pages of operating instructions while trying to locate a specific maintenance procedure.

C) What goals does the audience have when using the product and the technical documentation? When identifying the goals to be achieved, you should determine how familiar the audience may be with similar products, and when they are most likely to need the documentation.

If the product is a toaster, the audience can be assumed to be completely familiar with its operation. A microwave oven, however, would be a different story. More detailed information on the safe use and practical employment of the device would be in order.

You could satisfy the toaster documentation requirements by simply listing things that the user should not do. This can be in the form of liability disclaimers and warranty notices. The microwave oven would require additional information because not everyone has used a microwave oven and not everyone recognizes the epicurean changes that are required to cook with one.

## *Planning Technical Documentation*

Planning a technical document involves consideration of activities such as: Task Analysis, Storyboarding, Draft Preparation, Editing, and finally, Publication. As any experienced Technical Writer knows, document planning is the single most time consuming, confusing, and most important activity to perform. In some cases, the planning phase can occupy up to 60 percent of the total time applied to a project.

### *Task Analysis*

Task analysis is the process in which the Technical Writer analyzes those tasks that the product user will likely be called upon to perform. Perhaps the most important part of the planning process, Task Analysis allows you to meticulously plan the entire content of a document. While well-planned documentation addresses 'how to perform a specific task', task analysis breaks down major tasks into sub-tasks and tertiary tasks.

Task analysis can be visualised in a "top-down" configuration. If you identify the main task(s) to be achieved by the user, the sub-tasks that must be performed to achieve the main task should become obvious. As sub-tasks are identified, they can easily be divided into sub-sub-tasks until each has been broken down as far as needed.

A listing of tasks should be made to ensure that all tasks are identified and included in the document. A task analysis list for a colour television set may look something like the example shown in Table 1.

**Table 1 Task Analysis**

| | |
|---|---|
| **Product:** | ABC Colour Television |
| **Document Type:** | Owner's Manual |
| **Part Number** | 123-456-789-0 |
| **Top Level Task** | Installation And Operating Instructions |
| **Sub-task 1** | Basic installation and hook-up |
| **Sub-task 1.1** | 1st time operation |
| **Sub-task 1.2** | Cable-TV Connection/Operation |
| **Sub-task 1.3** | External Antenna Connection |
| **Sub-task 2** | Operating Instructions |
| **Sub-task 2.1** | Remote Operation |
| **Sub-task 2.2** | Front Panel Colour Adjustments |
| **Sub-task 2.3** | Video Picture Adjustments |
| **Sub-task 2.3.1** | Colour Adjustment |
| **Sub-task 2.3.2** | Tint Adjustment |
| **Sub-task 2.3.3** | Contrast Adjustment |
| **Sub-task 2.3.4** | Brightness Adjustment |
| **Sub-task 2.3.5** | Picture Reset |
| **Sub-task 2.3.5.1** | With Remote Control Unit |
| **Sub-task 2.3.5.2** | Without Remote Control Unit |

A technical document that does not include a clear description of the tasks to be performed by the user, usually ends up describing how well a product operates, but rarely tells the audience how to use it (achieve the goals). This can lead the audience to perceive the document as explaining how well a product has been designed. Remember, there are a lot of VCR's in the world that are only flashing 12:00.00; invariably, they were accompanied by documentation that told purchasers how sophisticated the product was, and how lucky they were to have bought it, but not how to make the thing work in a way that was understandable.

As seen in Table 1, the task analysis list will eventually identify the precise order that the information should be presented. The list can be used to generate headings which, in turn, will define the text content for each item.

When multiple audiences are involved, task analysis can become somewhat confusing. A Task-Analysis/Matrix Chart (Figure 1) can be used to keep track of the relationships that exist between the audiences and the tasks to be completed. Additionally, a matrix of this sort helps to identify missed tasks, and what product functions are irrelevant to one or more of the audiences.

### *Storyboarding*

The storyboarding technique allows you to visually map a document's structure, illustrate the flow of information, and define it's scope or content,

| Task Analysis By Chapter / Audience ID By Function | Audience #1 Management | Audience #2 Installers | Audience #3 Maintainers | Audience #4 Operators |
|---|---|---|---|---|
| Chapter 1 General Descriptions | X | | | X |
| Chapter 2 Installation | | X | X | |
| Chapter 3 Theory Of Operation | | | X | |
| Chapter 4 Operating Instructions | X | | | X |
| Chapter 5 Preventive Maintenance | | | X | |
| Chapter 6 Corrective Maintenance | | | X | |
| Chapter 7 Parts Lists | X | X | X | |

Figure 1.Typical Task-Analysis/Matrix Chart.

before beginning the writing process. Although storyboards are usually prepared using a computer and word processing software , the manual cut-and-paste methods still work.

Storyboarding produces a clear, detailed layout of each page in the document, thereby building a 'document model'. Such a model permits effortless experimentation with different layouts and designs, without undue cost increases. Proper storyboarding allows you to:

1. analyze the document flow and position the information to ensure readability and continuity,

2. solicit comments and suggestions from colleagues before freezing the design,

3. identify undue complexity in the document structure,

4. estimate the document's final size, and the associated production/publication costs.

Once a storyboard is complete, it should be approved by management, and the design (fonts and type sizes, graphics, layout, and binding techniques) frozen. At this stage, any changes should be minor in nature, and should not adversely affect the document's layout. Checking these minor changes against the storyboard will ensure that the 'document model' still works. If, for any reason, changes cause errors to appear in the model, you may have to repeat the task analysis process until a satisfactory model is re-established.

A typical example of storyboarding is illustrated in Figure 2.

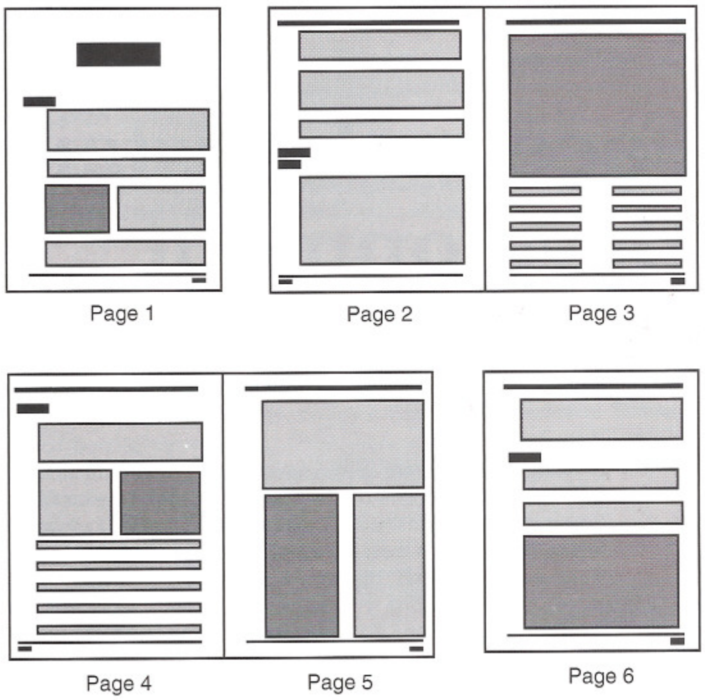


Figure 2. Typical example of storyboarding for a 6-page document.

### *Draft Preparation*

Creating a draft is a relatively simple task when audiences have been identified correctly, and the storyboards are complete. Once these functions are approved, the document should be about 75% complete.

A draft manual should be arranged such that steering aids, i.e. the table of contents or index, permit easy location and retrieval of information; that the writing style is adequate for the intended audiences; and that the information presented is correct and free of ambiguous descriptions.

### *Technical Editing*

While grammatical editing can be accomplished by a single, skilled individual who checks for spelling, grammar, and syntax, technical editing should be conducted in a group or team environment. This provides the opportunity to gain additional insight concerning the product and the document, and affords a learning experience that is not always possible during the product development phase.

Accepting someone else's constructive criticism is not always an easy thing to do. An Editor is an integral part of a documentation team and, as such, should only be concerned with producing the best possible document. Inexperienced technical writers sometimes find it difficult to see faults or inconsistencies in a document that they have spent considerable time working on. These individuals should remember that the Editor does not identify mistakes or errors, he/she simply identifies problems and suggests possible solutions.

### *Effective Use Of Illustrations*

In documentation, there are two types of illustrations: line art and half-tones. Line art comprises solid linework, produced either on a drawing board, using manually means, or by a computer. Manually produced artwork can be pasted onto finished text pages, while electronically produced artwork can easily be imported into most desk-top publishing applications. Half-tone artwork is generally a grey-scale reproduction of either an electronically scanned photograph, or some sophisticated artwork generated by computer applications like CorelDraw or MacDraw.

To be effective, illustrations must show sufficient technical detail which would otherwise require lengthy text descriptions. The detail found in technical illustrations must not confuse the audience, or cloud the accompanying text descriptions. While a picture may be worth a thousand words, a picture that is not easily understood, or calls for interpretation by the audience, is better left out.

## *The Inherent Liabilities Of Documentation.*

People who produce technical documentation should always keep 'product liability' in mind. Take, for example, a Service Manual that doesn't tell it's user (in this case a maintenance individual) that a grounded 3-wire power source is required to operate a piece of equipment. If the maintenance person decides to use the equipment in an area that does not have 3-wire grounded outlets, he may decide to cut the ground pin off the plug and perhaps electrocute himself.

If this happens, who is responsible? Is it the user, the product manufacturer, or the legal department for not insisting on sufficient liability disclaimers and Warnings, or is it the Technical Writer who didn't think a warning for such a basic common sense thing was necessary.

Ideally, a technical manual should be approved by a product liability specialist before it is printed and released for distribution.

## *Conclusions*

We have seen that clear and easy-to-read documentation is the end result of careful planning. Planning is the *only* way to produce any type of quality technical documentation, and the more planning that goes into a document, the more successful it will be. In many ways, a document's success can be measured by the response you receive from your audience. If the document does not meet the needs of the audience, they will let you know, usually by means of increased contact with your Customer Services department. Conversely, if the document satisfies the audience's needs, and lets them fulfil their goals, you will probably never hear from them.

Remember, the key to a successful technical document is planning, planning, and still more planning.

### *About the author*

**Terry D. M^c^Mullen** was born in Peterborough, Ontario, on April 27, 1958. He received technical diplomas in Architecture (1978) and Electronic Instrumentation (1984) from Mohawk College in Hamilton, Ontario. Mr M^c^Mullen has worked as a freelance Technical Writer for twelve years, documenting such military projects as sonar, radar, and weapons control systems, and diverse commercial products including banking and optical tracing equipment, computerized reservation systems, and digital photo enhancement software.

# Facets of Sustainable Development

## *In Search of Social Innovations and Solutions*

*by Walter W. Zessner*
*The George Brown College*
*of Applied Arts and Technology*

*"Not long ago, society believed that the environment was endlessly able to absorb the detritus of a modern industrial-based economy. More recently, the assumption was that the environment and the economy were inevitably opposed: opting for one meant damaging the other. Today, however, it is clear that the two, rather than being mutually exclusive, are mutually dependent: a good quality of life and economic development cannot be sustained in an ecologically deteriorating environment."*
Watershed 1990, Regeneration 1991, Final Report by the Royal Commission on the Future of the Toronto Waterfront.

*Il n'y a pas longtemps, la société croyait que l'environnement pourrait absorber éternellement les déchets d'une économie industrielle moderne. Plus récemment, il était supposé que l'environnement et l'économie étaient inévitablement opposés: Opter pour l'une allait au détriment de l'autre. Aujourd'hui il est clair que les deux, plutôt que d'être mutuellement exclusifs, sont mutuellement dépendants: Une bonne qualité de vie et le développement économique ne peuvent pas être soutenus dans un environnement en détérioration écologique.*

Providing for sustainable development on planet Earth in order to support a present population of 5.4 billion, estimated to exceed 6.0 billion by the year 2000 and 8.4 billion by the year 2020, probably represents the single most important challenge of modern times. That environmental resources, technological and other developments should be matched with humanistic survival needs, states a simple issue in principle, but one that poses complex and largely unsolved problems.

Can this challenge be met, to ensure a quality of life worthy of dignified living, which is presently lacking for a vast majority of people who exist under subsistence conditions in fragile ecosystems? Unfortunately, as long as a fuller understanding of the interrelated dimensions and magnitudes of this central issue remains vague and hazy, few remedial visions or solutions can be perceived or expected. Slower moving evolutionary processes and traditional accumulation of human experiences have been seriously disrupted during the past century of revolutionary scientific and technological changes that dictate a much faster pace.

In Canada, the experience of an unsustainable development received a dramatic ecological demonstration with the government policy announcement of July 2, 1992, whereby the Federal Ministry of Fishery implemented the suspension of northern cod fishing in Newfoundland for a period of two years. This moratorium was deemed unavoidable as a minimum condition for the gradual renewal of fishstock. Meanwhile, about 20,000 people whose livelihoods depend on this traditional fishing industry are out of work and added to the existing 20% local unemployment rate. Without effective agreements, international fishing will continue beyond the 200-mile zone of Canadian waters. At the recent UN Earth Summit meeting, no binding measures on overfishing could be established. Yet the efficiency of sonar, radar and other factory-like technologies for modern fishing exploitation entails a reduction of the survival chances for larger fish-schools to reach reproductive maturity. These highly "successful" fishing processes have been compared to the clear-cutting of forests. Without a doubt, triumphs of technology can impose socio-ecological tragedies.

The fishing banks of Newfoundland, once the richest in the world, were discovered in 1497 by Giovanni Caboto, who wrote enthusiastically that he only had to lower a basket into the sea to pull out a rimful of fish. When one assumes unlimited supplies, the need for sustainable resource protection becomes superfluous. The assumption of unlimited growth and consumption, a mainstream doctrine of progress until quite recently, prevents the perception and acceptance of sustainable limits as a moderate option. Akin to the unlimited growth of cancer cells, unrestrained growth can annihilate a healthy organism through pathological multiplications.

It can be contended that it was not government legislation that decreed the fishing suspension, but rather that nature itself set an end of the line through a disastrous depletion of fish stock resources. The Newfoundland debacle signals the collapse of a traditional and once thriving industry that carries with it the serious threat of a potential third world status decline for once modern, industrial regions.

This may symbolize contemporary global trends which are occurring 500 years after the discovery of the West Indies by Columbus. The discovery of the Americas, driven by the search for adventure, resources and riches, may yet leave an impoverished legacy for future generations who are no longer able to expand into resource-rich and thinly populated continents. Hence, a search for, and renewal of, sustainable resources needs to be actively advanced, preferably through rational means rather than being precipitated through the blind dictates of disasters and catastrophes. Diminishing resources spell doom for all species and organisms that took not centuries, but millenia to evolve.

Canada's dependency on diminishing natural resources and its encounter with tracts of wilderness no longer unspoiled, may partially explain its relatively higher awareness of the formidable deteriorations afflicting the globe. The familiar symptoms of ailing ecosystems include accelerating deforestation and loss of species, soil erosion and population stresses, growing atmospheric pollution by greenhouse gases and the ozone-eating chlorofluorocarbons (CFC's). "The threat of demise through despoliation and degradation of the planet ...-...the threat of perpetual endemic violence ..." has been increasingly detailed [1]. Although much publicized, words have all too rarely been heeded by deeds.

### *The Earth Summit Conference in Rio de Janiero*

Much attention and awareness has been generated through the initiatives of a Canadian, **Maurice Strong**. As Conference General Secretary of the United Nations, he brought 160 delegations together at the largest international meeting in history at the Earth Summit in Rio de Janeiro. At the closing plenary session, before the heads of states and dignitaries, a noteworthy conclusion was made by the impassioned address of a 12-year-old Canadian girl, **Severn Suzuki**:

*"Parents should be able to comfort their children by saying, 'Everything's going to be all right.' But I don't think you can say that to us any more."*

This unadorned urgency undoubtedly deserved the congratulations of U.S. Senator Al Gore, himself the concerned author of "Earth in the Balance: Ecology and Human Spirit".

The Rio Summit yielded few tangible results. Binding agreements have been frustrated, primarily by huge cost projections. The following presents a brief summary of resolutions that concluded the Earth Summit:

***Biodiversity convention***
A legally binding treaty to protect plants and animals in danger of extinction, signed by 153 countries. It obliges countries that use DNA-based genetic resources of a nation to share the research, profits and technology with that nation.

***Global Warming Convention***
A legally binding treaty that recommends curbing emission of carbon dioxide, methane and other "greenhouse" gases. A total of 153 countries signed the treaty, but without being bound to set targets.

***Rio Declaration on Environment and Development***
A non-binding statement of 27 broad principles to guide environmental policies. Included are statements that nations have a responsibility to ensure that activities within their borders do not damage the environments of other nations, and that protection of the environment constitutes an integral part of economic development.

***Agenda 21***
By consensus, this 800-page blueprint was adopted for action to protect the environment, while encouraging development. Implementation is estimated to cost $125 billion annually.

***Statement on Forest Principles***
A non-binding statement on protection of forests, consisting of a 17-point document. Sustainable management of forests is stressed as being important for economic, ecological, social and cultural reasons, including indigenous peoples' rights and biodiversity.

The much praised guideline for industrial-based economic development, namely "no development without environmental protection and no environmental protection without development," has been dampened by the criticism of the non-binding and "toothless" nature of most agreements.

Difficulties in achieving effective agreements on a global scale, primarily reflect the current obstacles in attaining local consensus and approval within nation-states. Objections are frequently rationalized with references to threats of global competitiveness. Less pointedly articulated is the prospect that environmental degradation is accentuated through lax national and international protective measures. Voluntary guidelines and vague target objectives merely symbolize good intentions without preventing a bad situation from becoming worse, as if reinforced by a vicious feedback cycle.

For the past 250 years, the liberal constitutions of Western nations have concentrated on individual rights, property and division of authority, which are not well-suited to protect communities and other public goods. Sustaining ecosystems involve complex interrelations that extend seamlessly from provincial to national to global boundaries, without paying heed to jurisdictional divisions of power. Since the by-products of industrial civilization cross borders, so must the authority to deal with them. Hence, it becomes essential to combine individual and governmental responsibilities that recognize community values and ecosystem realities, with methods and tools to pursue sustainability.

Some environmentalists would go one step further, urging an ecological declaration of independence or interdependence to match the traditional declarations or charters of human rights, which took centuries to evolve and are by no means universally implemented.

## *IEEE and the Environment Issue*

Many initiatives are advanced by scientific and professional associations, including the IEEE, to place the controversial, often adversarial, debates on environmental issues within a more objective and scientific perspective. The IEEE Satellite Video Conference, broadcast under the theme "Environmental Issues and Impact to Engineers" (May 28, 1992), is scheduled to be continued, and the presentations are available in VCR cassette format. The satellite conference was introduced (a) to exemplify methods at the design and manufacturing phases to improve quality and to reduce cost and environmental impact, (b) to focus on worldwide environmental issues as a key element of product design, and (c) to provide practical examples and applications such as presented by IBM, AT & T and XEROX.

A video series, demonstrating environmental surveillance methods and results using satellite technology, has been made available by the cosponsoring participants of the United Nations International Space Year 1992, with IEEE representation [2].

The Society for Social Implications of Technology (SSIT), once described as the conscience of IEEE, has addressed relevant socio-technical issues in the IEEE Technology and Society Magazine for over 10 years. The local Toronto SIT Chapter was able to bring the 1991 Biennial SSIT Conference to Toronto (June 20-21, 1991). This event, cosponsored by the IEEE Toronto Section, the University of Toronto and Ryerson Polytechnical Institute, related the conference theme, "*Preparing for a Sustainable Society*", to "*Our Common Future*", a report by the UN World Commission on Environment and Development [3]. The 1991 SSIT conference generated 70 papers that focussed on four main subject areas detailed as follows by the program co-chairs [4]:

1. **Defining the problem.** How will the relationship between technology and society change if a strategy of sustainable development is adopted?
2. **Redirection of democratic control.** Can society control and redirect the technological system it has created, or is the system now controlling society? Can engineers harmonize social values with technical and economic values?
3. **Dilemmas confronting the practicing engineer.** What are the problems faced by engineers attempting to make a particular technology more sustainable? (along a scale that favours the poles of zero impact as against the opposite extreme of maximum degradation through inaction and neglect).
4. **Engineering education for a sustainable society.** Will ensuring a "common future" require changes in engineering education?

Much deserved recognition for his pioneering contributions must be extended to the program co-chair, engineer and scholar **Willem H. Vanderburg**, Director of the Centre for Technology and Social Development at the University of Toronto. In a keynote address, Professor Vanderburg summarized that engineering and business decisions continue to be based largely on criteria such as efficiency, productivity and cost-effectiveness. These input and output ratios provide few indicators of how technical or economic change will fit into human, societal and natural contexts.

Small wonder that millions of such decisions have produced an environmental crisis and an undermining of the fabric of society. "Input/output measures are necessary in a resource-scarce world, but are not sufficient to ensure the health and quality of human life, society, and nature" [5]. Consequently, it is imperative to ensure a greater synergy between technology and its human, societal and natural context in areas of material design, production and energy systems.

Development of "preventive engineering" strategies by means of "ecology of technology" solutions can be shown to be more effective, environmentally compatible and cost effective. Preventive engineering aims to include ecologically-friendly conditions as inherent specifications for engineering designs. Minimizing the detrimental impact on the environment can prevent excessive waste, thereby conserving and saving material and energy resources, as well as assets. For example, the elimination of ozone-depleting CFC's, together with improved production techniques, saved millions of dollars for Northern Telecom.

## *A New Approach to Project Design*

The classical approach to project design perceives self-contained, independent artifacts and systems.This approach makes it understandable that considerations about sustainability could easily be sidelined to a marginal position – until fairly recently. Thus, environmental assessments and impact studies can no longer be viewed as infringements on technological development or even on creativity. Indeed, a creative redirection needs to be stimulated to make technological developments holistically integrated and environmentally compatible.

Traditionally, quality engineering is marked by prudent and careful worst-case design specifications that may have to include the impact of environmental consequences. Most project designs entail byproducts that impinge unavoidably on the environment. The scrutiny and farsightedness that is routinely devoted in establishing long-range technical standards, needs to be matched with technological requirements that meet sustainable criteria. Technical obsolescence, estimated to follow an average 10-year cycle, places an even greater emphasis on including integrated and long-range considerations.

While the achievements and boldness of Columbus, who dared the darkness of uncharted seas, need not be diminished, one should be mindful that the voyage of 1492 ended as an accidental landing on the West Indies and not on the projected East Indies. This monumental navigational miscalculation could never be repeated today given the precision instruments made available through technology. Assured accurate positioning in open sea sailing could only be accomplished with the aid of reliable instrumentation.

By analogy, the need to find a more reliable socio-technological bearing and orientation, to guard against dismal orientational self-deception, arises as a problem of modern times. What exactly are the socio-technical analytical equivalents to the compass and chronometer? With inadequate tools, one is bound to be led astray, cast adrift in uncharted and treacherous socio-technological waters.

The ever-accelerating pace of developing technologies makes it even more urgent to identify, in time, any damaging and "magnificent dead end" applications. Implicitly related are demands to facilitate our extrication from adversarial paralysis and systemic grid-lock, more mundanely experienced as traffic jams.

Crucial historical changes are making the need for sensitive analytical tools of social orientation paramount. This intellectual revolution, this introduction of sustainable development, could ensure a rational degree of humanistic sustainability that could vitalize the promise for a genuine "New World Order". ■

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### *About the author*

**Walter W. Zessner** immigrated from Germany in 1952 and worked with CBC TV Engineering from 1954 to 1965. He then combined his career of teaching technology subjects at The George Brown College of Applied Arts and Technology, in Toronto, with concurrent interests in the social sciences. Although retired from teaching, Professor Zessner continues to present research papers at interdisciplinary conferences and is currently Chairman of the IEEE Social Implications of Technology Society in Toronto.



# Cooperation vs Competition


*by Ray Findlay,*
*Director, Engineering and Management,*
*McMaster University*


Contrarily to the statements issued in recent months by our various levels of government, the recession in Canada seems to be getting worse. The most vulnerable sector appears to be manufacturing, as the combined policies of the federal and provincial governments make it more attractive for multinationals to close operations in Canada and move south of the border. Especially at risk are manufacturing plants in Ontario. However, the other provinces are not faring well either.

What have we done about it? Conventional wisdom has it that we should be exporting our technology, not the product. Consequently, we have spent the last three decades or so exporting expertise, with the predictable result that the Japanese, South Koreans and other countries, many we used to call "third world," have now substantially surpassed us not only in manufacturing but also in technical capability. This can readily be seen at any international conference by noting the number and quality of technical papers presented from Japan, especially.

Although the United States is suffering in some degree, with unemployment rates of about 6%, Canada has suffered an alarming double digit unemployment rate. The pity is that many of the jobs lost are in the technical sector. There are few jobs for our current graduates. Employment rates for newly graduated engineers from most schools in Canada are now running at less than 50%. Although graduates ultimately find positions, many of these jobs are not in engineering or technology. The graduates rarely come back. Once they become discouraged, they pursue other careers. Canada becomes the loser in this game.

Even worse is the situation for engineers who are displaced after ten or twenty years. This represents the loss of an enormous potential, and at a great cost to the people who find themselves out of a job. Canada loses out not only in terms of formal training, but also in terms of expertise born of experience.

There is something we can do about the situation besides the obvious approach to lobbying the various governments. We can instead lobby our companies to start changing their tactics. For example, North American industry is founded on the principle of competition, aggressive tactics on both the domestic and international markets. Japanese industry is founded on the principle of cooperation, joining together with others to carve a niche on the international market, instead of competing for an increasingly diminishing domestic market. If we want to emulate them we will need a complete change in philosophy. We need to espouse trust, cooperation and pooled research among our industries. Governments, industries and universities must combine talents to bring new technologies and products to fruition.

Universities need to emphasize team-building, project management, quality engineering and entrepreneurship as a regular constituent of engineering programs. Our governments need new strategies for developing this scenario, beginning with policies that encourage cooperative market ventures and concurrent product development. We, the professionals, should be sending the message to government, industry and university that we need to change if we are to survive in this new economic climate. ■

# The IEEE in Pre-College Education

## *Starting a Dialogue*

*by Robert W. Osborn, Ph.D., MIEEE*
*Osborn Management Consultants*
*Toronto, Ontario*

*Our public school system may not be adequate to the task of producing the next generation of engineers, and a technologically competent general workforce. Suggestions are presented for different ways by which IEEE Canada, and the members and companies of the engineering community, can be involved in the pre-college education system, and a new federal/provincial program is outlined. Our involvement can show educators and students alike that the industry is concerned and interested, that the engineering world is both fascinating and vital to Canada's future.*

*Notre système scolaire peut ne pas répondre adéquatement aux besoins de la prochaine génération d'ingénieurs et d'une main-d'oeuvre compétente sur le plan technologique. Des suggestions sont proposées par lesquelles le IEEE Canada et les membres des associations d'ingénieurs peuvent être impliqués dans un système d'éducation au niveau pré-universitaire, et un nouveau programme fédéral-provincial est illustré. Notre participation peut démontrer aux professeurs et également à la population étudiante que l'industrie est impliquée et que le monde du génie est à la fois fascinant et vital pour l'avenir du Canada.*

There were about ten of us gathered around the huge conference table in the local Board of Education Building. The questions were coming thick and fast: "What should be the marketing strategies for the changing image of education?" "How should local advisory committees be developed to coordinate the integration of technological education with academic programs?" and "How can technological literacy be developed as a basic skill for all?" and even "What *should* be the requirements for teacher education?" "What *should* be the requirements for a diploma?"

No, this was not a meeting of the Board of Education. (You should attend yours and see what they really talk about!). Nor was it an IEEE Section board meeting (ditto). All the above questions and hundreds more were being asked by our provincial Ministry of Education [1,2,3,4,5] and answered (over a two-year period) by small committees around the province. A few of these committees, like ours, were composed of industry and college representatives who were concerned about the kind of young people our public education system was offering us as employees and students. We were also concerned about how well Canada and its workforce were going to survive in a technologically competitive world - and where the next generation of Canadian scientists and engineers were coming from (eastern Europe? Asia?). And I, for one, worried about the current ignorance of basic science and technology that hampers voters and politicians and regulators: people with the power to affect me and my business.

Where do engineers come from? Think back... What lit the spark of technological curiosity, and what else fanned it into a flame in your life? For it is most certainly at an early age that this happened, much before the rigours of college and boring academicians threatened to douse the flame. I first learned about electronics around age 11, when my father gave me a radio kit. My school system didn't see fit to tell me much about it until 5 years later (long after I had built amateur radio transmitters), and I often wondered why.

Granted, not every high school graduate will go into science or engineering, but it is actually a wonder that *any* do at all. Those students who enjoy science or computers risk being called a "nerd" or at least considered odd. They need encouragement and direction, especially since they must take certain courses to prepare them for the ruthless academic requirements of college engineering programs. And the rest of the students, those who will be shopkeepers and clerks and lawyers and stockbrokers: they must also be urged to understand and question science and the technological changes. Granted, things seem better: I have seen grade 8 boys *and girls* operating all kinds of machines and hooking robots to computers - but the various standardized tests and studies (you've seen the headlines!) do not ease my fears that most of our young people are scientifically and technologically illiterate. Yet there is absolutely NO reason why our high school graduates could not know at least how the household wiring and switching circuits work, and how and why a personal computer works (or doesn't work). They'll need this to survive tomorrow.

Here is how one member of our committee (a local Hydro employee) prefaced his answer to the first question above, on the subject of getting kids interested in technology:

"The Minister of Education should ask what works for music, history and languages? It requires early exposure plus continuing demonstration of the intrinsic worth of technological knowledge and real-world application. Greater participation in the education process by technological practitioners from industry would be an effective element of the strategy. I see an analogy to the Russian dolls that nest together; as each one is opened another is discovered inside, each successive one smaller and thus more finely painted. In a similar way, technological education can be presented as the means of unlocking the increasingly exquisite mysteries of how things work or get done in our highly-developed, technologically-based society." [6]

This kind of appreciation didn't come from a textbook. The eager, questioning mind must be primed before any textbook is going to do any good. Perhaps this is where our industry can best help. And while the IEEE is an excellent educational institution, its tactics must be quite different when addressing the question of "Where do engineers come from?"

The private business community has been organized in this direction for a long time. They fund the "Junior Achievement" (JA) project, which has operated in Canada since 1955, and currently offers four quite distinct programs for grades 6-12, all aimed at getting kids together with "real-world" business people in discovering why business is so fascinating.

Several years ago, I taught a 9th grade course in business economics as a volunteer under the JA program; this involved one class hour per week for a semester. Before entering the classroom, I was given all kinds of encouragement, a 276-page *"Consultant/Teacher Manual"* [7] with lots of detailed ideas for class activities, and accompanying workbooks for the kids - plus organized meetings with the planners and several dozen other volunteers doing the same thing.

Since then I have often wondered why the engineering community wasn't doing the same thing!? I guess others wondered too, because three years ago the Federal Government (Industry, Science & Technology Canada) introduced two additions to its Canada Scholarships program:

- *"Frontrunners"* - to encourage university and college students to visit their peers at the elementary and secondary school levels; and
- *"Innovators in the Schools"* - to encourage technology professionals to do the same.

They maintain a registry of volunteers (with a target of 25,000) and a helpful guide: *"Selling Science to Students"* [8] for "first timers". Contact the program at (613) 993-9597 to register or for more information. The scope of these programs is not yet anywhere near that of the Junior Achievement program - but it is a great start. Quoting from their guide booklet: "The success of these programs proves that kids get more interested in science when they get a chance to see a real scientist, engineer, technician or technologist in action."

I still wonder why the engineering community - and IEEE Canada in particular - isn't leading this effort.

Of course, it isn't like wondering why the government doesn't bring down a progressive budget. In *that* case you must wait for the organization. In the case of education, it has always traditionally been the responsibility of the people of each community to make it work. That's you and me! And there are *many* ways to make it work - which don't necessarily involve standing in front of a classroom!

### *Attend a School Board meeting*

At least you can see what they plan to do with your tax money. Let them know that "industry" is concerned; see if they interested in having a Technological Studies Advisory Council, or Subject Advisory Committee. They may be simply looking to industry as a donor of cheap equipment; this is a good start, but a permanent advisory group could do more.

### *Join a Technical Advisory Committee*

If one has already been set up in your area. Meetings are usually infrequent, interesting, and occasionally challenging. Ours provides great food! This is the best way to see how the schools are teaching technology and to review the education materials and tools they are currently using. Be aware that schools use the word "technology" to include ALL kinds of technologies, so your fellow members may be from the auto industry or carpenters union. Be prepared for educational jargon like "thematic units", "de-streaming" and "articulation" (which doesn't mean what the dictionary says).

You probably won't be asked to determine curriculum requirements at these meetings, but it provides an excellent opportunity to ask questions and try new ideas. What computers and technology tools are in the schools - and are they adequately supported? Do the school libraries allow students to check out electronics kits, or computers and educational software for home use? Is technology being integrated into non-technology courses; for instance, does the English class include a unit on computer word-processing techniques and lexicographical information retrieval? Does the English teacher know how to use a computer?

### *Spread the Word*

The IEEE U.S. Activities Board (USAB) has produced two good pamphlets [9,10] on careers in electricity, electronics & computers - aimed at high school students. Since they do no good sitting in the warehouse, we obtained quantities of each and mailed them last March to the 147 members of the **"Ontario Technological Education Co-ordinators Council"**, who are designated by each school district to advise on such matters. The IEEE Canada office provided postage and much welcome assistance. The result was not great: there were only a few requests for more copies to give to students. Perhaps a local follow-up in each area would have achieved a better response. Certainly all of this should be done in the other provinces. At least get a few copies of the smaller brochure from IEEE Canada and hand them to your high school counselor.

### *Nominate an Editor*

For the IEEE *Spectrum* Precollege Innovative Math/Science Education Competition. While all winners to-date have been from the U.S., the competition is open to any Canadian educator (at the elementary or secondary school level) who creates a program to foster interest in and improvement of student accomplishments in mathematics and/or science subjects. (Descriptions of past winners are available from my office or IEEE Canada).

Since this is a pretty restrictive contest, why not follow the example of the IEEE Denver section [11] in instituting local awards for outstanding teachers?

### *Judge a Contest*

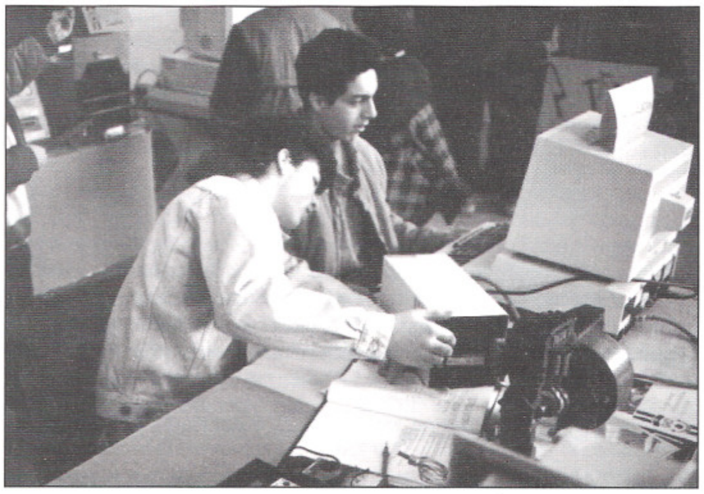
Usually there are various competitions involving science and/or technologies activities in your school district. The **"Skills Canada"** program, for instance, offers local and provincial contests in such areas as electrical wiring, CAD, robotics, etc. Winners get to compete in the U.S. Skills Olympics. Our district has a **"Sci-Tech Olympics"** for grade 6 students as well. Outside coaches, judges and observers are especially welcome for these events.

### *Get your Company to Hire Students and Teachers*

In some districts there is a **"Student Workplace Apprenticeship Placement Program"**, which allows selected students to spend some time in an industrial setting working as an apprentice. This program is aimed at students who are at risk of dropping out of school for several reasons: they need the stimulus of a more active type of learning or need to bolster family income. On the other side of the fence, Ontario requires that all technology teachers must have worked several years in industry before they can start teaching; also, many Boards provide an opportunity for teachers to return to industry for periods of time up to one year to update their industrial experience. All of these people especially need jobs to keep practical education possible!

### *Involve your Company or IEEE Section in a School "Partnership"*

This might work as follows: your company provides speakers or equipment or job-shadowing or "mentor" programs for students; the school can provide materials and teachers for a skills-upgrading or ESL (*English as Second Language*) program for your employees; both could share facilities for recreational purposes; and a host of other mutually beneficial exchanges.



Pre-college introduction to technology stimulates young students and provides them with lasting motivation. (*Photo courtesy of Norman Dale, City of York Board of Education*)

### *Speak to the Students*

This is best done through some kind of organized approach - and the obvious way is to register as part of the "Frontrunners" or "Innovators" programs mentioned above. If, for some reason, the idea of a national registry doesn't appeal to you or your local schools, start a local program to try things out. For example: involve your IEEE Section and one or two school districts. Ask your members who would like to speak on what topics; ask the schools (or the district technology consultant) what speakers they need - and you're off and running. Let other IEEE sections and schools know what you've done, and the idea may catch on. If you are interested in a longer program, contact the **Junior Achievement** organization at (416) 622-4602 for more information; there are all kinds of ways to introduce technology in a business context.

All of this can apply to tutors or "mentors"; for instance, the IEEE Rochester (NY) section joined with other professional engineering groups to offer technical tutors in a wide variety of subjects to one school district.

There is really no end to ideas. Maybe your group could create some short videotapes illustrating career alternatives (I think the kids would especially enjoy seeing the raw first "takes" and then the edited version!). Certainly your company and IEEE both should be involved in school "Career Nights" and have exhibits at appropriate events. For instance, my local school Board arranged a one-day career conference with about 30 exhibits from various industries (plus demonstrations and workshops) - for an audience consisting of girls in grades 7-10. Our IEEE missed that one, but maybe next year...

IEEE U.S. has offered some great examples of action programs. **George Watson**, Senior Editor of IEEE *Spectrum*, must certainly be commended for the contest (noted above) giving IEEE recognition to deserving educators. The US Activities Board has produced some great career pamphlets, and has been heavily involved in the **"National Engineers' Week"** projects (which in 1992 brought about 20,000 engineers into school classrooms). IEEE is also involved with 40 other U.S. engineering societies in President Bush's program for recruiting 100,000 volunteer engineers - about one for every school in the country. "The volunteers will lead science clubs, conduct classroom demonstrations, organize career days, guide field trips, guide and tutor students, arrange industrial internships for students and teachers, and substitute for teachers so the latter can attend professional conferences." [12]

In Metro Toronto it costs us taxpayers about $7400 per secondary school student per year. The educators are generally proud of the quality training they provide for this money; yet the Province has had to set up three expensive retraining programs to prepare young people for jobs. Recent statistics show that 30 % of our young people drop out of school, and of those that graduate from high school, about 17 % are functionally illiterate. Something is still amiss, and we are challenged!

**Arthur MacDonald** of Northern Telecom summarized this challenge as follows:

"To win in the markets of the world, Canada will require, will depend on, a corps of the most highly trained and broadly educated graduates possible. They must be second to none in their skills of communication, mathematics and, most particularly, science and technology.

"I place the stress on science and technology because these are the *enablers* that can sharpen our competitive edge in all sectors and activities of our economy. Technology and science are the crucial levers Canadians need to widen the windows of opportunity into the world marketplace.

"More than ever before, knowledge is power - the key to economic power. No one holds a monopoly on the world's expanding knowledge. The best you can hope for is that you can obtain it faster and use it better than your competitors.

"Whatever Sir Wilfrid Laurier said of the 20th century, the 21st century belongs to no one. The option facing us as a country is fundamental: Get on board or get left behind." [13]

When you get on board the education bandwagon, let us know your experiences. This should be an open dialogue, and should NOT be the last time the subject is raised in these pages!

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### *About the author*

**Robert Osborn** was born and educated in the United States, receiving his Ph.D. in Physics from the University of Rochester in 1973. He immigrated to Canada in 1976 to join the staff at York University for a short term. Fascinated with computers since writing his first Fortran program in 1965, Dr. Osborn has been involved with several leading corporations as a designer and manager of software development for scientific research, telecommunications and business applications. An IEEE member for many years, he served as Editor of the award-winning IEEE Toronto *Connection*. Dr. Osborn is active in Metro Toronto community organizations, and has served for the past three years as a member of the Technological Studies Advisory Committee of the City of York Board of Education.

IEEE ComSoc
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Abstract must include the title, the author's name, a complete return address, a telephone and a fax number. The 300-500 word abstract of no more than two sheets will include figures and/or tables. Five copies of the abstract in english must be sent to the local sponsor.

# Global R&D for Global Competitiveness

## *A Bell-Northern Research approach that ensures success*

*by Peter Scovell*
*Vice-President, Advanced Systems and Technology*
*Bell-Northern Research*

*The globalization of Bell-Northern Research has been a critical factor in the continued success of Northern Telecom in the world markets. This article, based on the author's address to the Ottawa chapter of IEEE, describes BNR's globalization process and identifies the factors that make the company an effective global organization.*

*Le succès inégalé que connaît le fournisseur d'équipement de télécommunications Northern Telecom sur le marché mondial, tient en grande partie aux efforts sans précédent que sa filiale de recherche et développement, Recherches Bell-Northern, a consacrés à la mondialisation de ses activités. Cet article, inspiré d'une allocution présentée par l'auteur devant les membres du IEEE ((chapitre d'Ottawa), décrit l'ensemble du processus qui a assuré le succès du programme.*

Global R&D for global competitiveness is an important issue which has become very relevant to members of the IEEE.

Electronics and electrical engineering are at the very heart of the Information Age. The technological advances you've pioneered and applied — with similar breakthroughs in computing — are enabling a whole host of new communications services.

This growing capability to access, share, and manage information, in virtually any form, has been a major force in creating today's global marketplace. But this outstanding achievement has also brought with it a fundamental new challenge: competing — and winning — on a global scale. This key priority is one that my company, Bell-Northern Research, has been addressing ever since the company was incorporated 21 years ago.

Today, BNR has grown to become the largest R&D organization in Canada, and a global leader in the telecommunications industry. We now have labs in Canada, the United States, the United Kingdom, and Japan, as well as development teams in other countries around the world.

I want to share with you some of the experiences we've had in building this global organization. Specifically, I'd like to look at why we've globalized and how we've globalized. Let me begin with why.

### *The Whys of Globalization*

Many people question whether a company, like BNR, really has to open its technology function to the outside world. And by that, I mean outside Canada. My answer to that question – without hesitation – is "yes". It's not an option. It's not an alternative. It's a *necessity* of survival in the global marketplace. There are several major reasons why it is essential.

One, is proximity to markets. The products that BNR develops for Northern Telecom must fit into a worldwide telecommunications network. Although these products have to meet technical requirements that are common to all countries – in order to guarantee basic telephone service – they also must meet the many diverse requirements of individual countries.

Each country has its own government regulations, its own standards, and its own technical specifications. We have to be close to the customers in those countries in order to truly understand and respond to their unique needs and individual requirements.

We also must be there influencing and learning about new standards to be adopted. They will determine how our products will function and interwork with networks within those countries.

The second reason for globalizing the R&D function is that it brings to our organization new technologies and new ways of doing things. This is important because different regions show strengths in different technologies and different processes. To succeed on a global basis, it's essential to link into these technology hot beds and draw that knowledge back into our global organization.

The third major reason for globalizing the R&D function is that it actually promotes growth within the home country; it does not detract from it. For example, twenty-one years ago, when the R&D labs of Northern Electric officially became known as Bell-Northern Research, we had 1800 employees located at one site in Ottawa.

Today, we have 4500 people working in Ottawa, and that original site now supports several major labs. One of those facilities is our Advanced Technology Lab, which rivals the best in Japan, Europe, and the United States. This lab is dedicated to developing high-speed gallium arsenide integrated circuits and advanced optoelectronic lasers – two fundamental technologies for the multimedia communications of the '90s.

This fall, we will be officially opening our fifth lab in the nation's capital. When this lab is completed, it will bring the total capital investment at this site alone to $500 million and the total square footage to more than 1.3 million. That's the equivalent of about four Toronto Skydomes.

So, we've had tremendous growth within Canada over the last two decades. The point I want to make, however, is that if we had not grown outside Canada, we would not have been able to support this growth inside Canada.

Let me put that into perspective. Twenty years ago, almost all of Northern Telecom's revenues were generated from Canadian sales. Last year, 50 percent of the total revenues came from sales in the United States, and 26 percent from sales outside of North America – the latter is now our fastest growing market. So the simple answer to the question "Why globalize?" is that it makes good business sense.

### *The hows of globalization*

Now that I've examined some of the why's of globalization, I'd like to share with you some of the how's; the models, or recipes, we've found to make globalization work for us.

There are essentially three ways to globalize: through green-field growth; through acquisition; and through partnering with other corporations. Let me begin with green-field growth, in other words, starting from scratch.

### *Green-field growth*

Most new labs go through a familiar growth pattern, which can be characterized by three stages: infancy, adolescence, and adulthood. During the infancy stage, we start with a small embryo group, whose initial tasks usually involve customizing the corporation's existing products and technology for a new market.

I say "usually involve" because it's not a hard-and-fast rule. Our lab in Tokyo, for example, actually began with BNR engineers doing co-research with Nippon Telegraph and Telephone – a major customer of Northern Telecom.

We've found that during the infancy stage, it's essential to establish a buddy system, whereby the new group works with a group in the home base. This teaming provides moral and technical support and – like the traditional buddy system – it keeps the new lab from drowning. Once the lab establishes a foothold in the new market, it enters the adolescence stage. In other words, it begins to take on independent development projects.

By taking on progressively more complex assignments, the lab enters adulthood– usually within a five-to-six-year period. At this point, the lab not only serves the needs of its local market, it also becomes a source of product and technology innovation for all other labs in the BNR network, often specializing in specific technologies and products.

### *Acquisition*

In addition to green-field growth, the second way we have globalized our R&D activities is through acquisition. Our most recent experience began last year, when Northern Telecom acquired STC – one of the leading telecommunications suppliers in the United Kingdom.

Parts of STC merged with Northern Telecom, and other parts – specifically the engineering divisions of STC – joined BNR. Northern Telecom's acquisition — which, according to *The Wall Street Journal* was one of the 10 largest last year — has given us a very strong foothold in Europe.

It has also presented some challenges. Virtually overnight, BNR acquired 1200 new employees. This brought our total population in the United Kingdom to more than 1300 people. Our primary challenge has been to integrate two different cultures, two different product lines, and two different ways of doing things – without losing the best of either organization.

To help achieve this goal, we created an umbrella organization called BNR-Europe. Our BNR lab in Maidenhead, England and the newly-acquired STC engineering labs all report into this umbrella organization.

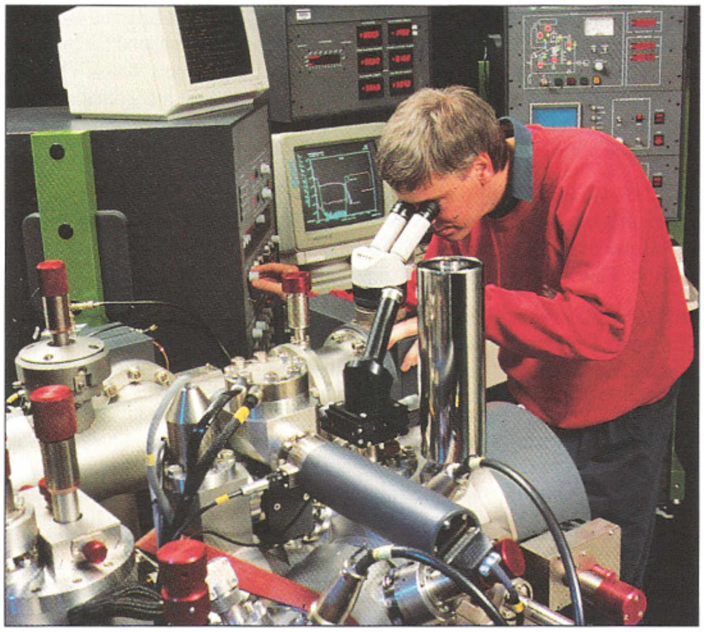


Figure 1. Scientists in the Advanced Technology Laboratory at BNR-Ottawa use this sophisticated system - called secondary ion mass spectrometry (SIMS) - to investigate optoelectronic devices and very-high-speed integrated circuits (ICs) through different stages of their prototype fabrication. Here, **Tom Moore** adjusts the position of a sample under investigation to allow the ion beam to probe another section. The area probed is about the diameter of a human hair.

Figure 2. **Deborah Clark** loads and positions an indium phosphide wafer inside an electron cyclotron resonance deposition system, where a dielectric coating is deposited on the wafer surface. This machine was custom-built for BNR to achieve the high-quality thin films needed to fabricate optoelectronic devices.

Experience has taught us that to succeed in acquisitions, it's important to pick indigenous leaders. So, the individual we chose to head BNR-Europe was from STC, not from BNR. We then supported that individual with an equal number of second-level managers from both organizations.

In any acquisition, it is inevitable that projects will overlap and some will become redundant. As a result, it's essential to start new projects immediately after the acquisition – projects that combine the strengths of both organizations and lead into the new strategic direction.

The sooner new projects are identified, the sooner that people working on projects that have become redundant can be reassigned, the sooner you can begin to build the new organization.

Although it is still too soon to judge our effectiveness in merging the BNR and STC cultures, I'm extremely pleased with the progress, the energy, the enthusiasm, and the creativity that is being generated by the new organization.

### *Partnering*

The third way we have globalized BNR's R&D activities is through partnering with other organizations. The major lesson we've learned in this area is that it's important that partnerships be formed for strategic reasons, not simply tactical ones.

By that, I mean it's important to form a partnership because you're strong in a particular area, not because you're weak. To do that, it's necessary to look at the long-term benefits of the partnership – instead of the short-term gains that could be made by filling a product gap or other shortcoming. Northern Telecom's recent joint venture with Motorola, for example, will bring the very powerful strengths of BNR's leadership in digital networking with Motorola's expertise in radio.

No matter how globalization is accomplished, however – whether it's through green-field growth, acquisition, or partnership – it's essential that the organization functions as one team, with one vision. And that brings me to the final area I want to consider: how to ensure the effectiveness of a global organization.

## *Effectiveness of a global organization*

Essentially, the effectiveness of an organization will depend on the infrastructures that are put in place to support (1) global communications, (2) project and people management, and (3) technology transfer. Let me briefly consider each of these requirements, beginning with communications.

### *Global communication*

The effectiveness of an organization can only be maintained if information flows quickly and effectively among its dispersed locations.

In BNR, our communications network is particularly vital because many of our major development projects are being co-developed at two or more sites. As a result, we must rely on the most advanced technology available. More and more, it is a corporation's communications infrastructure that gives the company its competitive advantage.

Global infrastructures are also needed to support the management of people and projects across multiple sites. At BNR, we have created two complementary management structures. One is a fairly flat, geographic structure. The other is a very fluid, horizontal project structure, which cuts across location and laboratory boundaries.

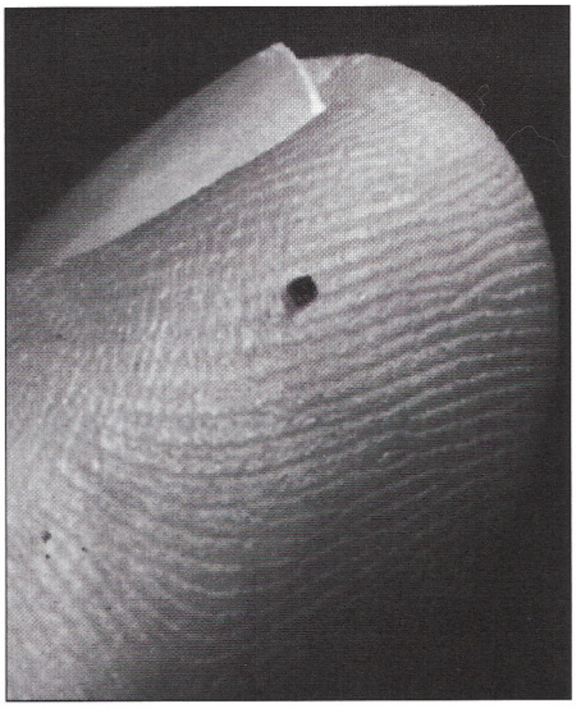


Figure 3. The salt-grain-size speck on the finger is a breakthrough semiconductor laser that can make fiberoptic telecommunications to the home an affordable reality. Produced by scientists and engineers at Bell-Northern Research, the research and development arm of Northern Telecom, the unique device uses a circular grating, similar in appearance to the tracks of a compact disk (CD) , to reflect a powerful column of light upward. A world's first, the new laser could enable a crucial component in fiber-optic systems — the electronic-to-light interface modules — to be manufactured for a fraction of today's cost of hundreds of dollars each.

### *Project and people management*

Experience – some of it learned the hard way – has taught us that the management of a specific project is most effectively run by a single project manager, no matter how many different labs are involved. This person is responsible for project content and milestones across all sites. The responsibility for the management of people, on the other hand, is vested with managers at each individual location.

When we open a new BNR lab or transfer a project from one site to another, we typically transfer people from the prime technology site to the new location.

We have found that the ideal length of time for the expert to stay at the new lab is bi-modal – either less than six months or more than three years. These time frames seem to bring the best results to the corporation and to the individual – for economic, social, and personal reasons.

### *Technology transfer*

Technology transfer is the third consideration in building an organization's global infrastructure. Because knowledge is the lifeblood of an R&D organization, it is essential that the core knowledge of a corporation continues to grow and to be transferred throughout the organization.

This transfer of information can happen in one of two ways. The first is electronically. To make this transfer of information as smooth as possible, it is important that a corporation use common communications systems throughout the organization. The second way to transfer information is through people.

All of these requirements for a global infrastructure are important. However, they must not stifle innovation, originality, or independent development. Furthermore, although it's important to work within the infrastructure, the organization must encourage – and the infrastructure must support – diversity.

## *Conclusion*

I've tried to highlight some of the most important challenges of global R&D. And though my examples have been based on BNR's experiences, I think many are relevant for your organizations as well.

If our industries are to be major players in the global marketplace, they must also be major players in the global technology pool. Markets are international, and technology-enabled competitive advantage is a major lever for global growth.

As members of the IEEE, we have virtually unlimited opportunities to apply our technical expertise to design products and services for people around the world. I find that an extremely exciting prospect.

At BNR and Northern Telecom, we have set ourselves an exciting goal for the future. That goal is to be the world leader in telecommunications by the year 2000. And we're confident that goal can be achieved.

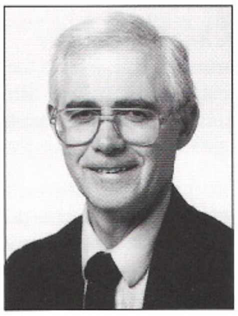
Why? Because just 20 years ago, Northern Telecom was a small Canadian company, virtually unknown to the rest of the world. Today, Northern Telecom – largely as a result of the worldwide success of the products and systems BNR has designed – is the third largest telecommunications manufacturer in the world.

And, without a doubt, that position has been reached only as the result of BNR and Northern Telecom's efforts to aggressively seek – and meet – the challenges, the opportunities, and the rewards of globalization. ■


### *About the author*

**Peter Scovell** is currently Vice President, Advanced Systems and Technology for Bell-Northern Research (BNR), based in Ottawa, Ontario. He has been active in the management of technology throughout his career. Born in London, U.K., in 1951, Mr. Scovell earned his bachelor of science degree in Physics from the University of Leeds in 1973. In 1977, he was awarded a Ph.D. degree in theoretical physics, also from the University of Leeds. After graduating, Mr. Scovell held various positions with STC PLe in the U.K. In December 1990, he joined Northern Telecom Electronics, in Ottawa, as Assistant Vice President. In July 1991, Mr. Scovell was appointed to his current position with Bell-Northern research. He is currently responsible for a number of BNR's strategic initiatives including optoelectronics, silicon design, and the University interaction program within North America.

## IEEE Annual Election
## *Élections annuelles du IEEE*



As a result of the balloting for the 1992 IEEE elections, **Dr. Raymond Findlay** has been declared Director-Elect for IEEE Canada in 1993.

Dr. Findlay, a registered professional engineer in the Province of Ontario, received his B.A.Sc. (1963), M.A.Sc. (1965) and Ph.D. (1968) degrees from the University of Toronto in Electrical Engineering. He taught at the University of New Brunswick (1967-1981) before joining McMaster University.

His research interests include fields and losses in electrical power devices in which he has over 100 technical papers and 2 patents. In 1989 he won the IEEE Regional Activities Board Award for Innovation.

Dr. Findlay has served IEEE in may capacities over the past twenty years at the local, national, and international level for both Regional Activities and Technical Activities.

Dr. Findlay will become the next director of IEEE Canada for the two-year period, 1994-1996.

## Call for a Managing Editor– IEEE Canadian Review

The IEEE Canadian Review Advisory Board is actively seeking a volunteer to fill the position of Managing Editor of the IEEE Canadian Review. The mandate of current editor Ted Wildi will expire on September 1, 1993, and the person who will then take over should begin tenure of office on or before June 1. This will ensure a smooth transition and a gradual transfer of editorial know-how.

Managing the Review offers excellent opportunities to participate in IEEE affairs across Canada. The Managing Editor is a member of the Executive Committee of IEEE Region 7. The Review is a dynamic going concern, well supported by an experienced infrastructure and a group of devoted Associate Editors.

For more information, please contact **Tony Eastham**, Chairman, IEEE Advisory Board; Tel (613) 545-6081, Fax (613) 545-6853.

## Russ McDowell takes over as Advertising Manager

Tony Eastham, Chairman of the IEEE Advisory Board, is pleased to announce that **Russell McDowell** has volunteered to take on the important job of Advertising Manager of the IEEE Canadian Review.

Russ is well known to members of IEEE, having contributed his talents in support of the engineering profession in many tangible ways. He served as Chairman of the IEEE Ottawa Section during 1988-89, acted as Region 7 Public Awareness Coordinator during 1989-91, and was Chairman of the Eastern Canada Council 1991-92.

A specialist in computers, Russ has worked on several IEEE Standards activities, including writing graphic definitions for the P610 Computer dictionary project and reviewing IEEE Software Engineering Standards. Russ McDowell is currently employed at SHL Systemhouse in the Ottawa branch office as a Project Director.

Russ McDowell is a Senior Member of the IEEE, a registered Professional Engineer in the Province of Ontario, and holds a Master of Electrical Engineering Degree from Carleton University.

## FIBER OPTICS APPLICATIONS AND TECHNOLOGY SYMPOSIUM (FOATS '93)

FOATS 93

A Joint Initiative of the Canadian Society for Electrical and Computer Engineering, and the Montreal Sections of the IEEE and IEE (UK)

**April 29, 1993, 8:30 am to 5:00 pm**
**Le Centre Sheraton**
**1201 René Lévesque, Montréal, (Qué.)**

The symposium is designed to address the pressing need for a uniquely Canadian perspective on Fiber Optics technology and applications. Topics include Broadband and Fiber Network Enabled Services, Fiber in the Cable industry, Fiber trends in Europe, Evolution of Active and Passive components, the Economics of Fiber, etc. A half-day tutorial will be held in parallel to the lectures. This tutorial will cover Fiber Optics issues in technical detail. Planned tutorial topics will address Multi-Mode and Single-Mode Fiber Optic Transmission, as well as Amplifiers, LEDS and Lasers.

| **REGISTRATION FEES*** | **Early** | **Regular** |
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| Luncheon | $ 35.00 | $ 35.00 |

*Early registration ends March 5; additional fees for tutorial.

For further information, please contact **Pierre Allard**, Chairperson, at ph: (514) 870-3265, fax: (514) 870-9560

*We urge you to reserve early, since registration for the Symposium closes at 300 participants, and only 100 reservations will be accepted for the luncheon.*

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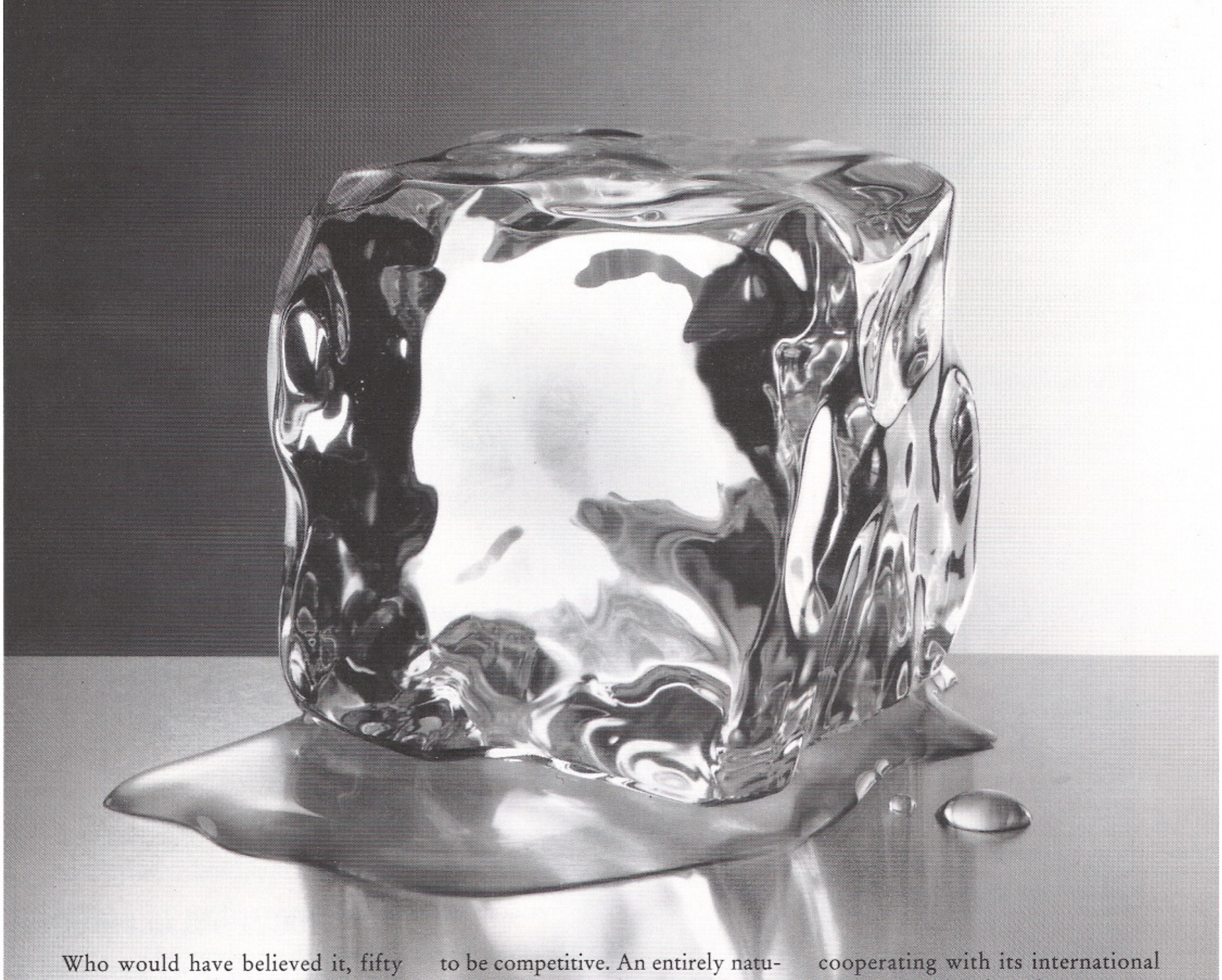

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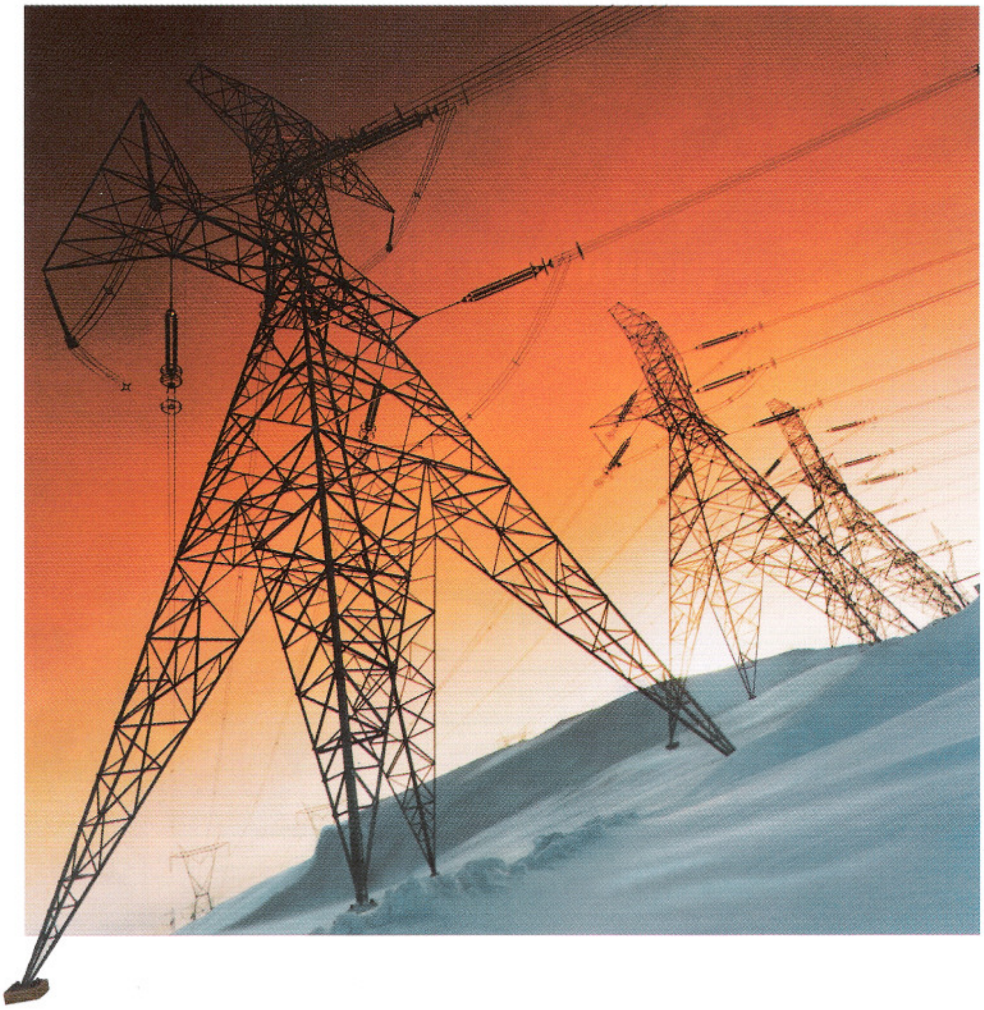

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