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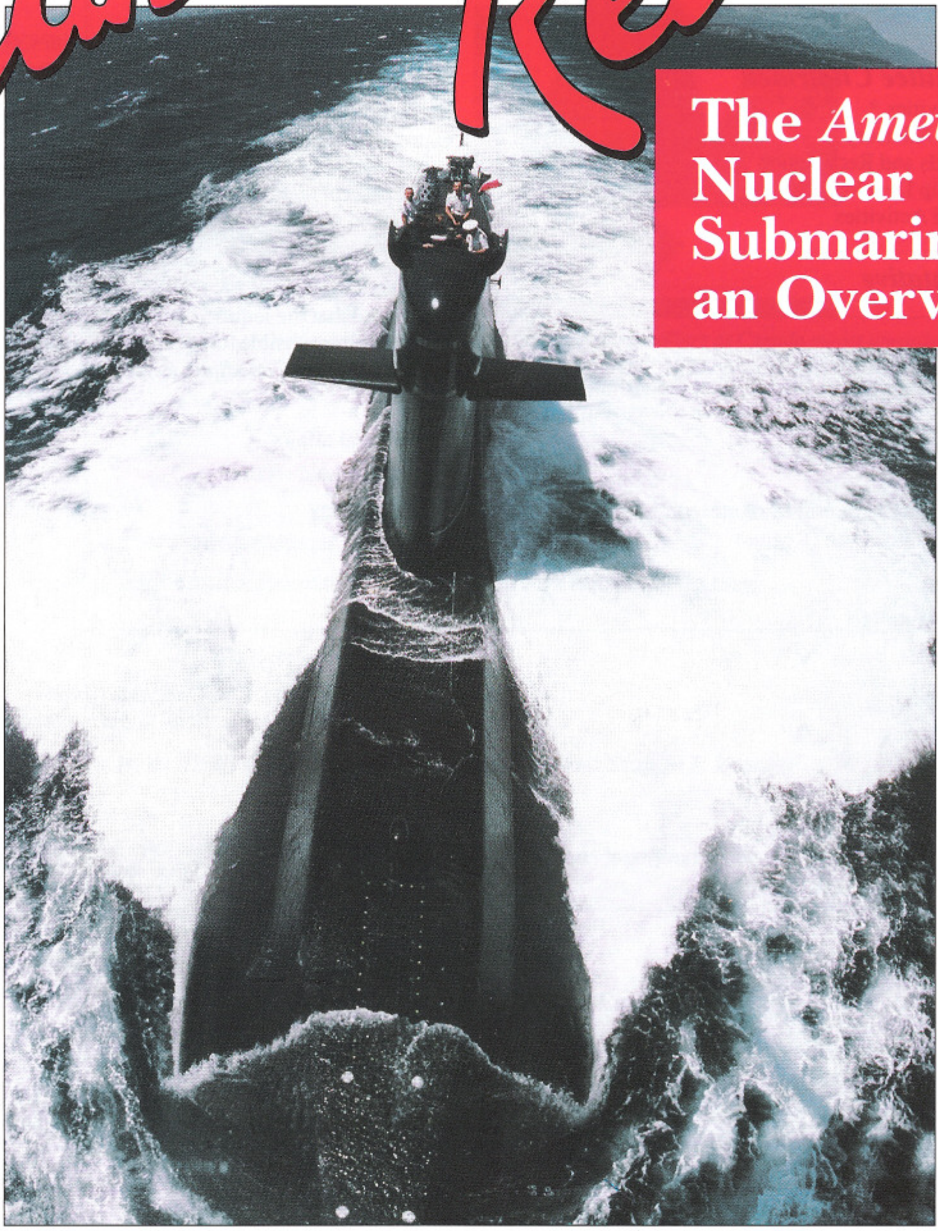

The *Amethyste* Nuclear Submarine - an Overview

The Institute of Electrical and Electronics Engineers Inc.

IEEE Canada

Mailing address:

7061 Yonge Street
Thornhill, Ontario
L3T 2A6
Canada

Telephone: (416) 881-1930
Fax: (416) 881-2057

IEEE Canadian Review General Information

The *IEEE Canadian Review* is issued quarterly - in March, June, September and December. 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, etc.), government and business communities in Canada.

In this context, the *IEEE Canadian Review* will also serve as a forum to express views on issues of broad interest to its targeted audience. These issues may not necessarily be technologically-oriented but will be treated on the basis of their anticipated impact on engineers or their profession, the augmented academic, business and industrial community or even the community at large.

To ensure that the *IEEE Canadian Review* have the desired breadth of issues and that the required depth of analysis be achieved, five 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- Technology
4- Industry scene
5- Education

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It is the policy or the *IEEE Canadian Review* to reduce production costs by inviting reputed organizations to place corporate-type advertising in the *Review*.

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The circulation of *IEEE Canadian Review* is the entire membership of IEEE in Canada, that is, 15 000 readers.

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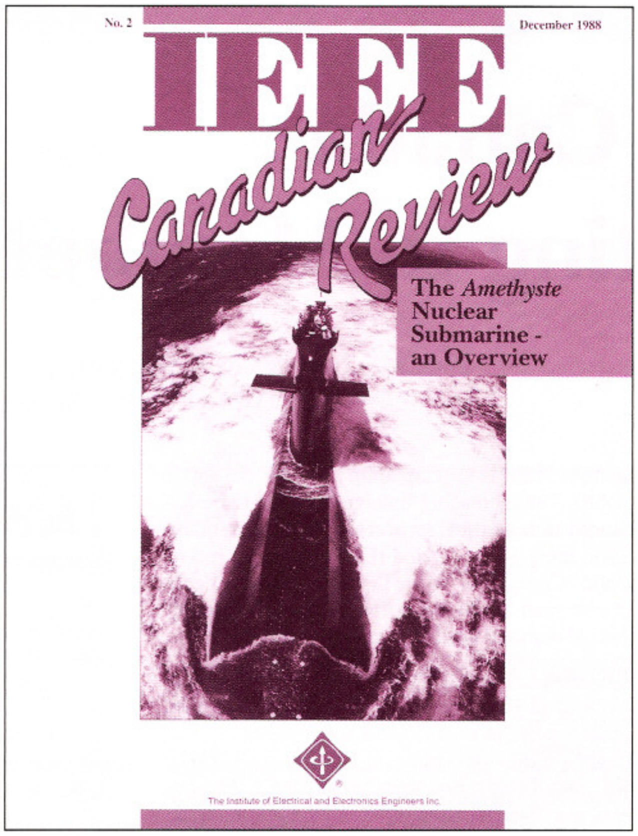
Information for Authors
Authors are invited to contribute to the *IEEE Canadian Review*. To this end, please contact the appropriate Associate Editor or IEEE Canada.

- The Managing Editor



Nuclear submarines are making headlines as Canada moves towards a major strategic commitment. In this issue, one of the contenders in line to supply SSNs -as they are called- to the Canadian Armed Forces lifts a corner of the veil on this little-known technology.

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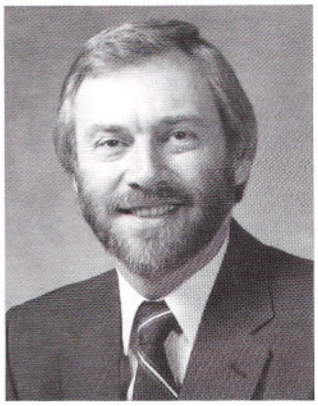
IEEE Canadian Review is published quarterly by IEEE Canada. IEEE Canada is the Canadian Region of the Institute of Electrical and Electronics Engineers, Inc. **Address:** 7061 Yonge St. Thornhill Ont. L3T 2A6 Canada. Responsibility for the contents rests upon the authors and not upon the IEEE, or its members. **Telephone:** (416) 881-1930. **Annual Subscription Price:** Free of charge to all IEEE members in Canada. Price for non-members on request. **Reprint Permissions:** Abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons. Instructors are permitted to photocopy isolated articles for non-commercial classroom use without fee. For other copying, reprint or republication, write to Manager of Canadian Member Services at IEEE Canada. Printed in Canada. Postage paid at Montréal Canada. **Postmaster:** Send address changes to *IEEE Canadian Review,* 7061 Yonge St., Thornhill, Ont. L3T 2A6 Canada.

IEEE Canada : Adapting to Member Needs

by Dr. Robert T.H. Alden
Director, IEEE Canada



One of the strengths of IEEE is its adaptability to meet the needs of the membership. The increasing linkage between the electronic (information) and electrical (power) sectors of our industry led to the 1963 merger that created IEEE. The more recent decision not to add "Computers" to the Institute's name reflects the reality that computer hardware, software, and philosophy have become an integral part of our total industry rather than a third sector.

The number of technical Societies within IEEE has grown to 35. This reflects the membership's need to focus on specific areas of expertise. However, they still maintain the broad overview of the profession. The three largest Societies (based on membership) are: Computer (90,000), Communications (24,000), and Power Engineering (21,000). Society publications were initially of the "Transactions" type and these remain the cornerstone of technical quality for Institute credibility. However, the majority of Society members realized that "Transactions" articles were usually too specialized for general knowledge reading in that technical area. Thus the development of Society "Magazines" to meet the need of these members.

IEEE Canada is evolving in response to the needs of our members, and the industry we serve. Our *Canadian Review* seeks to complement the other IEEE publications you receive with timely topics of interest. Judging by the initial response to our first issue, our editors are on the right track. In this issue, we explore the need for management skills in engineering, research funding, the PCB scare and introduce our readership to a small part of the nuclear submarine story.

We are also charting new ground in the area of conferences. A committee, chaired by Harry Prevey, is developing a "State of the Art Symposium" to be held in Toronto in the Fall of 1989. This event is planned as a major contributor in meeting the need for real technology transfer in the Canadian context at the engineering and management level. Please read Harry's article on page 6 of this issue about the Symposium. We hope you will plan to attend.

Both of these new ventures, the *Review* and the Symposium, are intended to present relevent and high quality information, as well as providing a forum for discussion of issues. These are distinctly Canadian initiatives that build on our publication and conference experience. As the technical society that serves, by far, the largest number of professionals in the Canadian electrical and electronics engineering community, IEEE Canada has evolved over many decades to fulfil the need for a Canada-wide technical society that links industry, government and educational institutions.

About the IEEE

The Institute of Electrical and Electronics Engineers, Inc. (IEEE), with headquarters in New York, is a transnational organization with 300,000 members in 137 countries. The world's largest engineering society, its objectives are technical, professional and societal.

The IEEE's technical objectives center on advancing the theory and practice of electrical, electronics, communications and computer engineering and computer science. To meet these objectives, it sponsors conferences and meetings, publishes a wide range of professional papers and provides educational programs. In addition, the Institute works to advance the professional standing of its members. It also has a mandate to enhance the quality of life for all people through the application of its technologies, and to promote a better understanding of the influence of these technologies on the public welfare.

Today, the IEEE is a leading authority in areas ranging from aerospace, computers and communications to biomedical technology, electric power and consumer electronics. When it began its second century in 1984, it rededicated itself to Innovation, Excellence, the Exchange of information and the quest for improved Education. In so doing, it underscores the initials IEEE.

IEEE Canada is the Canadian entity of this transnational organization, with approximately fifteen thousand members. The Canadian Region is divided into twenty Sections, each centered in a Canadian city, from Victoria, B.C., in the west, to St. John's, Newfoundland, in the east. For information on whom to contact in your area, the many IEEE products and services available, or how to join IEEE, write, phone, or fax our IEEE Canada office (page 2).

PCBs : Myth and Reality

Canadians have developed a fear of PCBs out of proportion to the real risk they represent to society which prevents the siting of disposal facilities.

by Hans R. Konow and Francis S. Bradley,
Canadian Electrical Association
Montréal, Québec

In years to come, 1988 will likely be seen as a watershed year in terms of the environment. During this year, politicians have made the environment a central plank in their election platforms while newspapers and newscasts have virtually overflowed with the immense volume of news on environmental issues.

In the United States, radioactive waste is reported leaking from nuclear weapons supply factories. Thousands of dead seals, presumably poisoned with some toxic substance, have washed up on the shores of the North Sea. Ozone depletion has opened a hole in the ozone layer in Antarctica. Contaminated medical waste has littered beaches in the Eastern United States. And the global warming trend, thought to be caused by emissions from fossil fuel combustion, is linked to both drought and flooding in different parts of the world.

Public opinion polling carried out for the Canadian Electrical Association earlier this year has indicated that 96 per cent of Canadians feel that environmental pollution is an important problem. And 71 per cent think the level of pollution has increased over the past two years. These facts were not lost on politicians competing for the moral high ground during an election year in Canada and the United States. Environmentalism has emerged as good politics and "sustainable development" has become the touchstone of Canadian environmental policy thinkers.

PCBs: Still an Issue ...

Solving the PCB problem requires that this difficult social and technological issue be dealt with in the only manner that befits a complex, multidisciplinary problem: the hard facts, however difficult to face, must be known, the public must be clearly informed and our collective strategies must be based on these facts.

Les BPC: de nouveau à la une ...

Les problèmes socio-technologiques difficiles à résoudre, tel celui des BPC, doivent être traités de la seule façon qui convienne à leur complexité multidisciplinaire: on se doit de connaître les faits, aussi difficiles soient-ils à accepter, on se doit également d'informer le public et enfin, nos stratégies collectives doivent s'appuyer sur ces faits.

Personalizing the Problem

But the event that hit closest to home for many Canadians was the PCB fire at Saint-Basile-le-Grand, Québec. Why? Because the impact was immediate and personal; and PCBs enjoyed a reputation as a human health hazard of almost mythological proportions. Newspapers and newscasts showed the tired and angry faces of the 3,500 people, who could easily have been friends, neighbours or relatives, evacuated from their homes and, for three weeks, housed in gymnasiums, church basements and campers.

Throughout this period of intense media coverage, it became evident that many of the enduring myths about PCBs were quick to surface in a climate of uncertainty and fear. When combined with a high level of public concern over environmental issues generally, it is regrettable, though not terribly surprising, that the gravity of the situation was once again inflated out of proportion.

The Culprit

PCBs or polychlorinated biphenyls just might be the most vilified chemical known to man. While Canada is certainly not alone in having singled out PCBs for stringent control measures, we seem to have developed an almost hysterical concern over them.

How did PCBs come to have such an unsavory reputation and what are the myths and realities surrounding this controversial chemical compound?

The Toxic Myth

The first myth is that PCBs are a deadly, toxic chemical capable of causing cancer in humans exposed to it. The origins of this myth go back to 1968 when some 1,300 people from Yusho on the island of Kyshu, Japan, became ill from consuming rice oil contaminated with a PCB heat transfer agent. The victims developed a severe and persistent form of chloracne (a severe skin rash) after eating the rice cooked in oil which contained 2000-3000 parts per million of a Japanese brand of PCBs. The disease progressed beyond just skin disorders, with some victims reporting fatigue, nausea, swelling of their arms and legs and even liver disorders. Eleven years after the exposure, 51 Yusho patients died and of the 31 whose cause of death was established, 11 or 35.5 per cent, were due to cancer. Only 21.1 per cent would have been expected in a control group. The media were quick to report this finding as proving that PCBs were linked to liver cancer.

However, since the beginning of this decade, scientists, like Dr. Stephen Safe of Texas A&M, have found that the toxic agent in the Yusho incident was not PCBs.

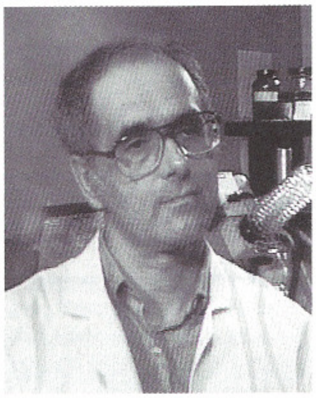
According to Dr. Safe, "a couple of studies, one by my own group and another by a group in Japan, conclusively show that the toxic agent in the PCBs that leaked into the rice-oil, were in fact not PCBs but a more toxic agent called chlorinated dibenzofurans." These dibenzofurans can be created when PCBs are heated.

Further research was undertaken to try and determine whether PCBs themselves could be linked to human diseases, including cancer. Researchers looked at groups that had been heavily exposed to PCBs, particularly those occupationally exposed.

Three studies, conducted by the National Institute for Occupational Safety and Health in the United States, looked at workers who had higher than normal PCB levels in their blood and had been exposed to PCBs occupationally for up to 40 years. All three studies found that cancer rates amongst the workers were slightly lower than the national average and that there was no indication of ill effects.

According to Dr. Walter Harris of the University of Alberta, "an enormous amount of information has been received and it's obvious that transformer workers, from the 1930s, '40s, '50s and '60s, using PCBs day after day, were not adversely affected in terms of their health. Simply put, PCBs do not appear to represent an important health hazard to human beings."

And in terms of the actual level of toxicity of PCBs, Dr. Renate Kimbrough of the Centre for Disease Control in Atlanta, Georgia, notes that "if you talk about taking a single dose of something, PCBs are not toxic at all. They have a moderate-to-slight toxicity."



Dr. Stephen Safe

According to Dr. Safe, "a couple of studies, one by my own group and another by a group in Japan, conclusively show that the toxic agent in the PCBs that leaked into the rice-oil, were in fact not PCBs but a more toxic agent called chlorinated dibenzofurans."

The Persistence Myth

The second major concern regarding PCBs relates to their persistence, once released into the environment. PCBs are a very stable compound which do not easily break down in the natural environment and, therefore, can accumulate in the food chain. It was this stability that made them attractive as an insulating fluid due to their high resistance to fire. A myth has now developed around this characteristic: PCBs, once released into the environment, are there forever.

The reality is that PCBs, while persistent, do in fact break down within the natural environment. Since the use of PCBs was controlled in the late 1970s, the level of PCBs in the environment has been dropping steadily and will continue to do so. In fact the New Jersey Institute of Technology has discovered an aquatic plant that can actually use PCBs as a nutrient, making it a biological ally in cleaning-up certain contaminated sites.

The Destruction Myth

A third myth holds that PCBs cannot be safely destroyed. Public concern over the siting of destruction facilities in Canada, for instance, has virtually blocked the elimination of PCBs, even where they have already been taken out of service. The result has been a proliferation of PCB storage sites leading inevitably to the type of incident which recently occurred at Saint-Basile-le-Grand. And while this incident, which caused thousands to flee their homes for nearly three weeks, caused no discernable health effects, it is not truly a case of "living happily ever after." The economic and emotional costs of this enforced interruption of people's lives cannot be dismissed lightly.

The reality is that PCBs can readily be destroyed through a number of conventional processes in complete safety. There is no need for them to be stored around the country in ever-increasing quantities. While most storage facilities are safe when managed according to accepted industry and government standards, there remains a risk. Unscrupulous businesses may emerge to take advantage of this growing storage problem leading to further Saint-Basile-Le-Grands. Alternatively, owners of small volumes of PCBs may act irresponsibly and dump their holdings illegally rather than face prolonged storage and disposal problems. These risks can be avoided.

Dr. Harris notes that "PCBs are organic molecules, extremely stable organic molecules, but they are still organic molecules, and like all organic molecules, they are broken down by high temperature. So they can be destroyed by high temperature incineration." Lower concentrations of PCBs can be treated through a chemical process, leaving harmless hydrocarbons and table salt.

However, only one PCB incineration facility has been built in Canada, at Swan Hills in Alberta. Safe and proven technologies for destroying PCBs are not being built elsewhere in Canada for one reason, the NIMBY (not-in-my-backyard) syndrome, thereby preventing Canada from eradicating its PCB stocks. Recently, the federal government has taken steps to rent mobile destruction facilities, but it remains to be seen whether they can be deployed effectively.

The Result

To sum up, the mythology that has grown up around PCBs has, on the one hand, led to a very costly phase-out program, diverting attention from other more pressing environmental problems, and, on the other hand, has prevented the siting of destruction facilities which would lead to a final solution to the problem. Research to date clearly indicates that PCBs are neither deadly nor cancer-causing; nor are they a permanent fixture in the environment. Furthermore, it has been demonstrated around the world that PCBs can be safely disposed of through high-temperature incineration and chemical processes.

The difficulty in doing so stems from an unwarranted fear of PCBs which inhibits the siting of destruction facilities. Governments, working with industry and environmental groups, must use information programs to dispel the myths surrounding PCBs so we can get on with the job of ridding ourselves of this pesky chemical.

IEEE Canada - State of the Art Symposium '89

by W. Harry Prevey - Symposium General Chairman

In 1845, a conversation was transmitted by telegraph between Hamilton and Toronto. This was about the start of the Electrical Electronics Industry of Canada. During the intervening 145 years, Canadians have developed the silent energy of electricity for instant communication with places near and far, for lighting and heating our homes, driving our machines of production, transporting our people and products, operating our office buildings, lighting our streets, controlling our traffic movements, calculating our scientific problems, doing our accounting, carrying out a great variety of medical treatments, and for educating and entertaining ourselves.

Today, Canada, a country with a small population in an extremely competitive world, stands among the most advanced in the art of producing, controlling and using electricity in all applications from micro-small to powerfully-big. Our future, as a growing country with a complex and diverse population, can only be sustained within the advancing family of developing nations through the continuing development of our technical capabilities.

IEEE Canada's roots go back to the beginning of the 1900s. For almost 90 years, this organization has been devoted to the advancement of technology in all aspects, across Canada, in all areas and all segments of society, through technically advanced professionals of all types and in all industries related to electrical developments. Today, this organization boasts 15,000 members in Canada and is part of an international organization of almost 300,000 members - all of whom are devoted to these same goals.

IEEE Canada has planned an "overview" type of discussion to be held at the Royal York Hotel, in Toronto, during October 23 and 24, 1989.

This Symposium is designed to deal with important questions about Canada's future welfare in the face of rapidly advancing technical developments which are taking place worldwide. Where do we stand today? What are our prospects? How will we compare with other countries? What contribution can we make towards solving the problems of energy, pollution, and the growing needs of a complex mass of people in an ever expanding world?

Speakers who are recognized authorities and leaders in industry, education, politics and institutions are being summoned to meet and discuss these important aspects of our country's future. The plan is to direct this discussion through the broad areas of Communications, Computing, Electrical Power and Industrial Automation. Within each of these areas, the discussion will include an appraisal of the State of the Art and requisite programs in Education, Development of Capable People for the electrical- electronics Industry, Research and Development and International Marketing.

For more information contact Harry Prevey - General Chairman, Bill Noll - Technical Program Chairman, or Terry Smirle-Registrations Chairman. All of these individuals may be reached through the IEEE Canada Office (page 2).

Research Funding in Canada : Strategy or Bridled Opportunity?

Canadian industry's recognition of the importance of science and technology is still not a priority in corporate financial planning.

by Dr. Alan C. Frosst
Assistant Vice-President, Research Services
McMaster University, Hamilton, Ontario

The Canadian research community is looking back over the past two years with excitement about the increased recognition of research and development (R & D) and technological innovation as essential components for economic growth. Announcements by various government levels of financial assistance programmes for R & D efforts have generated optimism in both the university and industrial sectors.

Researchers have responded with enthusiasm, rejuvenating efforts and forging new linkages. Across the country, there seems to be a widespread expectation that the future will prove the worth of increased R & D.

Looking ahead, however, there should be considerable apprehension about how the necessary tools will become available to pursue the economic challenges that Canada faces. In particular, there should be a far greater concern regarding the manpower requirements during the next decade and the capability of universities to educate research graduates, the next generation leaders.

The grand appearances of governments' R&D funding opportunities and incentives are not all that they have been made out to be, for real increased levels of funding have not been forthcoming. In fact, for the university sector, inflation costs have not been met for several years and the buying power of research funds for essential fundamental research activities has diminished alarmingly. By conservative estimate, academic researchers are operating at about the level of ten years ago.

This unfortunate situation leads one to question whether R&D funding policies in Canada are strategically sensible. Have we simply caught ourselves in a pattern of bridled opportunity that will lead us nowhere?

The Canadian R&D Environment

Most Canadians knowledgeable about R&D do not believe that this country has a definitive policy for science and technology. In fact, the "InnovAction" program is largely seen as nothing more than a collection of sporadic government announcements about re-allocations of resources. "InnovAction" is not a strategic plan, and it certainly has not addressed the real issues associated with the important aspects of research funding in Canada.

Canada's Gross Expenditures on Research and Development to Gross Domestic Product (GERD/GDP) ratio of 1.3% remains significantly lower than that of other industrialized nations (2.3-2.8%), and indications are that it will not increase. A realistic goal for Canada is 2.0%, considering the absence of a meaningful defence R&D effort. That level of R&D expenditure is needed today if this country is to establish the foundation required for the nineties.

It is well appreciated that the critical industrial component of the GERD/GDP ratio, amounting to 0.7%, is disproportionately low. This is between one-third and one-half of that in other countries of the Organizations for Economic Cooperation and Development (OECD). Regrettably, this is a statement in itself: Canadian industry's recognition of the importance of science and technology is still not a priority in corporate financial planning. When one accounts for less than 100 companies performing more than 80 per cent of the R&D, the industrial situation is of great concern.

Crossroads...

Canada contributes an estimated 1.5% of new knowledge to the world pool of science and technology, yet our industry must be able to access, when needed, the total pool. This process requires an increasing intellectual resource, provided only by our university graduates. If this country is to win its bid to fuel its economic growth through technology, a cooperative industry - university relationship is absolutely essential, building upon the strengths of both sectors. However, we must not permit short-term goals to substitute for strategy in the longer term, especially if our capacity to produce new graduates or pursue basic research is undermined.

À la croisée des chemins...

La contribution du Canada aux nouvelles connaissances du bassin scientifique et mondial se situe à environ 1.5% du total. Toutefois, l'industrie canadienne doit pouvoir accéder à la totalité de ces connaissances et seul les diplômés universitaires permettent d'y avoir accès. Pour gagner le pari d'alimenter sa croissance économique par la technologie, le Canada devra privilégier une relation coopérative entre l'industrie et l'université, bâtissant sur les forces de ces deux secteurs. Cependant, on ne peut permettre à des objectifs à court-terme de tenir lieu de stratégie à long terme, particulièrement si, ce faisant, on porte atteinte à notre capacité de produire des nouveaux diplômés ou d'effectuer de la recherche fondamentale.

With such a paltry industrial effort, the much sought-after and vital increase in its commitment to a respectable 1.4% — which would promote Canada to a total GERD/GDP ratio of 2.0% — is not a reality. More worrisome, it now appears that industry's contribution could even decrease slightly during the current fiscal period.

What we are contending with, therefore, within our feelings of enthusiasm, is a simple reshuffling of the existing pot. The result, however, is a very changed research funding climate within which researchers are expected to maintain previous levels of activity and embark on a wealth of new activity.

The Challenge to Industry and Universities

Within this constrained environment, industry and universities alike are experiencing tremendous adjustment pains, as each sector tries to adapt to the challenges and take advantage of apparent new opportunities. At the same time, they are attempting to maintain strengths rooted in their foundations. This is particularly true of our universities, which must continue to provide their educational programmes and maintain a strong base of fundamental research.

For industry, the challenges of technology have introduced major concerns, such as: how to access technology; how to evaluate technology; how to acquire it; how to use it; how to manage it; and, most important, how to create new market niches with it. As the manufacturing sector refocuses on international markets, new levels of creativity and entrepreneurship are demanded, requiring new management of technology techniques that many industries are finding difficult to cope with.

For our universities, the challenges are staggering. For instance, they must continue to grapple with the effects of an accumulation of provincial underfunding policies. In addition, expanding enrolments, new education requirements, rapidly changing technologies, out-of-date instructional and research equipment, deteriorating buildings, new expensive information system requirements, and a Canadian public that does not understand any of these matters while demanding "more," are the key issues which must be met in a context of decreased availability of funds.

And last but not least, the changed research funding climate must come to grips with the need to encourage participation without strangling the very essence of the fundamental research base.

Many consider the current focus on collaboration between university and industry as of a strategic necessity. That could well be. Others consider the climate a bridled opportunity that will serve only to whittle the universities' major research role while fostering subsidized surrogate (industry) applied research efforts on campus.

Our world is deeply engaged in a changing time. It is, however, a challenging time for all of us who are deeply interested to make a contribution for the future of Canada.

For this country, the stakes are enormous in our drive toward an economic future, while the consequences will be far-reaching if we fail to make prompt and effective decisions. But, we have the capability to create our own future through the one renewable resource that is ours to control: the intellectual resource. This is a short term renewable resource, a continuum of creativity and education, and the strength of the relationships between our industry and university sectors is vital to its vigour. How we promote that is up to us and our own initiative, energy, and entrepreneurship. How we develop that relationship and opportunity will determine whether the R&D opportunity is strategic or bridled.

Universities and industries together are the creators of this nation's wealth. Industry creates the value-added wealth or material wealth gain, while the universities create the intellectual resource wealth and make significant contribution to industrial capability through spin-offs from the extensive research activities. If this country is to win its bid to fuel its economic growth through technology, it will require a cooperative relationship, to form the parts into a collective whole. And nowhere is this more important than in the area of R&D and technological innovation.

The Financial Picture

Canada contributes only an estimated 1.5 per cent of new knowledge to the world pool of science and technology, yet our industry must be able to access, when needed, the total pool. This process requires an increasing intellectual resource, provided only by our university graduates. Unfortunately, as we digest all of the new funding programmes and incentive opportunities, it must be appreciated that, in Canada, we are starting an uphill climb from a base of science and technology that is approaching financial receivorship. Unless a real effort is made to improve the situation, by 1992, the end of the five-year Matching Fund Policy, science and technology will be bankrupt.

Those statements may seem, at first, to be contradictory with the excitement referred to earlier. They are, and for very good reason. The money that should have been put into basic research is the very same money that is now focused through the federal granting councils' University-Industry Programmes and allocated to other programmes, such as the Networks of Centres of Excellence. The excitement arises from the distinct new opportunities for universities to collaborate with the industrial sector. Concomitant allocations for certain industry-centered R&D promote new linkages with the university community.

The key question is, however, "Will industry respond?". In 1987-88, the National Sciences and Engineering Research Council (NSERC) granted $23 million of the budgeted $25 million under its University-Industry Programme. For 1988-89, it has budgeted an equal amount, although the government's policy offers $40 million. Next year, the level rises to $64 million.

Trying, however, to get industry to invest in this new game of collaboration is another matter, for, as pointed out earlier, it is expected that industry's portion of the GERD/GDP ratio of 0.7% may well be declining. It certainly is not increasing to the necessary minimum level of 1.4%. Industry needs to take a solid look at itself and ask the question, "Do we want to invest in the growth of this country or do we intend to continue sucking its resources?"

With more specific focus, when one examines the NSERC support for basic research through its operating, equipment, and infrastructure grants, the situation becomes acute.

Currently, the buying power of NSERC's budget for fundamental research is at the pre-1980 level. By 1992, without infusion of new funds, it will have deteriorated to the 1972 level. Today, NSERC supports some 6,700 university researchers, compared with the 3,000 that the NRC supported in 1972. Within just the past five years, it has added over 500 new researchers to its roll.

What is needed immediately is an injection of catch-up funds for the loss due to inflation during the past eight years plus a 0.1 GERD/GDP ratio increase in government funding through the granting councils for fundamental research in our universities. That level of funding needs to be indexed to inflation for five years, then reviewed and reinforced if necessary.

Obviously, the present situation cannot support the level of R&D effort required. Put on top the identified need for two-to-three times the number of current Ph.D. graduates by 1995 and the looming disaster is obvious.

Conclusion

For now, the name of the game is "collaboration," and, indeed, there are substantial opportunities that can be built upon for the entrepreneurially-minded researcher, in either university or industry. The money is there. It requires creativity, initiative, and corporate backing (in both the industry and university sectors).

Specific strategies will evolve unbridling the funding situation and resolving part of the dilemma. It will, however, take a concerted effort, in view of this country's needs for a new wave of competitiveness in an international context. Canada needs a broad spirit of leadership and initiative to accomplish that.

However, the government, industrial, and university sectors must get a collaborative act in order for the long term investment while those of us involved in and responsible for R&D in Canada must make our contribution in the short term with what we have available.

Do we have what it will take? When free trade, or, more appropriate, economic integration becomes a reality, will our lack of planning and investment be our downfall? Perhaps the answers lie partly in the initial question, "Is research funding in Canada a strategic or bridled opportunity?" Certainly, strategy is not apparent.

About the Author

Dr. Alan C. Frosst is Assistant Vice-President, Research Services, at McMaster University in Hamilton, Ontario. He is well known for his active involvement in the promotion of science and technology in Canada. During the past year, he was on Research Leave, investigating technology transfer in British Columbia and across Canada and assisting NSERC in fostering its creative University-Industry Programme.

Transition : Engineer to Businessman

Success in engineering does not guarantee success in business management.

by Gordon English
Associate Editor, Industry Scene
IEEE Canadian Review

Changing Careers ...

The transition from a technically-oriented role to that of running a firm, large or small, is not an easy one! Nor does it follow that because a person has been successful in problem-solving and decision-making in an engineering role that these same skills will lead to success when applied to operating a business.

There are specialized skills and aptitudes that are essential to the success of an engineer who wishes to expand his horizons by becoming involved in the development of his own business. Experience has proven that the well-trained engineer may not be very adept at assessing these skills in himself or in others. He may also not be prepared to deal with the risks involved in the launching of a commercial enterprise, not to mention the adjustments in life-style and working conditions that usually are found in the start-up phase of small companies...

Un changement de carrière ...

La transition de la carrière d'ingénieur à celle de gestionnaire de compagnie, quelle que soit la taille de cette dernière, est rarement facile. Par ailleurs, il n'est pas évident qu'un individu, dont les capacités techniques et de prise de décision ont été éprouvées avec succès dans le milieu de l'ingénierie, connaîtra le même succès en affaires.

L'ingénieur qui voudra élargir ses horizons par la mise sur pied de son entreprise propre devra donc manifester des qualités et des aptitudes particulières, essentielles à son succès. Et au-delà de ses compétences ou de sa valeur personnelle, l'expérience démontre aussi que l'ingénieur ne reconnaît pas ces aptitudes avec facilité, à la fois, en soi ou chez les autres. Enfin, l'ingénieur doit apprendre à vivre avec le risque inhérent au démarrage de petites entreprises sans parler des ajustements requis au plan des conditions de travail et de son style de vie...

Some of our successful "Hi-tech" businesses have evolved from small companies started by engineers. Many more ventures into the realm of business undertaken by engineers and technically-oriented people have not survived or have remained small despite the ambitions of their founders. What makes the difference?

As a young man undergoing military training, I was impressed by the fact that the majority of those being trained thought that leadership and the ability to command required no special capabilities, anyone could do it! However, watching the greatest critics of our leaders fumble their way through periods of what was termed "Mutual Instruction" convinced me that there was more to the business of leading than was first apparent. It was a lot easier to follow clear, concise commands than it was to plan and deliver them under pressure.

An engineer who goes to work in industry today, if he is any good, will soon find himself in a position of leadership and command. It may be as a project manager or engineering team leader. In any case, he will be called upon to direct or manage the activities of others, leading them towards the objectives he has the responsibility of reaching. This form of command may not require much business skill but will undoubtedly call for the intelligent application of "people skills". Successfully directing the activities of others is an important ability, one that is essential to advancement in an organization. Those of us who have the natural ability to lead will advance rapidly if that characteristic is coupled with drive and ambition.

But being a successful manager in an engineering role does not automatically qualify one to start and run a business. True, you may have demonstrated well developed "people skills" and an ability to manage time and resources, but those capabilities are only part of the qualifications needed to be a successful businessman or an entrepreneur. We have all witnessed the sad failure of the ambitious, would-be entrepreneur who leaves the security of a well-established engineering position to start his own venture. What went wrong?

To find the answer to this question and to many others like it, I have interviewed and discussed the subject with some people who obviously know the answers: successful engineers who have also become successful businessmen and who have demonstrated a strong entrepreneurial capability. I have also quizzed "Venture Capitalists" and investors about the characteristics essential to business success and how they identify these in the many investment opportunities they evaluate, particularly in the electrical and electronic segment of industry. Though no simple answer exists, it is clear that many of the pitfalls awaiting the aspiring engineer-turned-businessman can be avoided.

The Successful Entrepreneur and His Environment

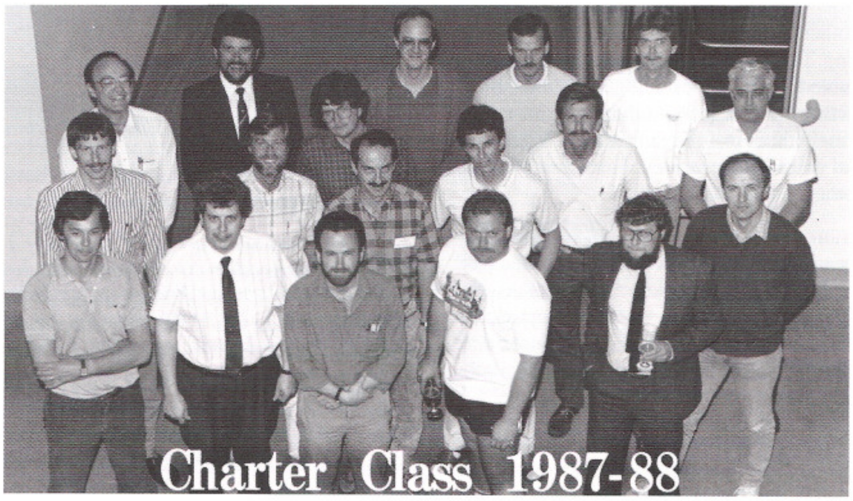
Hugh Kay, President of the Electronic Manufacturers Association of British Columbia, a Professional Engineer who has built several successful companies from small beginnings and who has also worked inside large corporations puts it very succinctly. "To be a successful entrepreneur one must learn to be comfortable with risk". This thought is, of course, contrary to good engineering practice where all known risk is overcome by sound design and ample safety factors. I can recall telling an engineering team that I was leading that I had no trouble at all in making a decision when presented with all of the facts! Who wouldn't? The trouble is that we never know nearly enough facts when making business decisions. The amount of guessing that goes on at the management level can give engineers ulcers in very short order if they have not learned to live with risk! Learning to work with and through people is another essential. That, coupled with decisiveness in a loose framework, need to be second nature in the businessman and entrepreneur.

Entrepreneurial activities are not confined to small start-up operations either. Large corporations are now encouraging more and more independence in their operating divisions and are stimulating innovation and experimentation at lower levels of management. Don Lowry, Executive Vice-President, Network and Customer Services at Alberta Government Telephones (AGT) advises that engineers must demonstrate a desire to be trained in other specialties. Technology is presently changing so rapidly that technical qualifications are simply not enough. AGT looks for those who have potential for at least three levels higher up the corporate ladder when contemplating promotion of engineers. This means that advancement will come most quickly to technical personnel who also have training related to management and business activities.

Does this mean that an MBA is an essential qualification for conversion from engineering to management? Not necessarily! Of course, there is no doubt that the extra degree is very helpful, particularly in large organizations, but it is not essential. A few well-chosen extension courses may also do the trick, particularly if one is going to go into a business of his own. The most important thing for the engineer to learn is that management is another discipline! Just as an engineer would not expect an accountant to be effective in solving engineering problems, neither should he expect to be able to make immediate sense out of a balance sheet. The biggest mistake is to think that successful business activity is just the application of common sense! True, without the liberal application of common sense, a small business is not likely to survive for long, but it also needs to be monitored and managed through the application of sound business principles that have to be learned.

Many technically-oriented people believe that their technical knowledge is of greatest importance to the small company they envisage and that they will hire the business expertise as it is required, using consultants or adding to their staff as the work load increases. Not a bad plan, if they are prepared to turn over the management responsibility to others. Unfortunately this is not always done. The experts are consulted but, if the ultimate responsibility still rests with the founder, he may make the wrong decisions because one rarely has enough facts to make the decision obvious. In my experience, confirmed in discussions with others who have successfully converted from a technical role to one of business management, the manager must understand business principles in order to make sound business decisions. Accepting input from experts is helpful, but the buck has to stop somewhere and there is no one to pass it to if you are the boss.

Tom Purdy, a Professional Engineer who learned business management inside a large multi-national company, confirms that there is more to good management than just the application of common sense. One has to develop budgets, manage budgets, direct operations, plan for the future, and most important of all, motivate the people reporting to him! Tom believes that to be a successful entrepreneur, an individual must be self-motivated, have vision, and be aware of the odds. If an engineer goes into business and finds that he lacks some of the essential abilities, Tom feels that this does not necessarily have to result in failure, provided that the engineer is prepared to share the profits and some of the glory with others who have the skills he lacks. Under these conditions, he must not be greedy but does need to be a good bargainer. If he fails this test, then he needs to seek a more protected role inside a structured environment. Founders of technical businesses rarely have the ability to lead that business through all its growth phases. Knowing when to step aside and turn over leadership to someone more suitably qualified is the greatest business wisdom one can develop.



1988 Graduation class of the Simon Fraser University program on Management Skills in Advanced Technology.

One of Western Canada's greatest hi-tech successes, Mobile Data International (MDI), nearly failed because of the lack of the right kind of management. Mike Brown, of Ventures West, the venture capital company whose patient funding and nurturing of the fledgling mobile data company kept it alive through its difficult start-up period, feels that it is difficult for engineers to build a management team and to adjust to the demands of marketing. "The technical founder" he says "can be very important to the company and plays a crucial role in the early stages of a technical enterprise but he must recognize need for help at an early stage and make additions to the team when things are going well rather than waiting until its too late". Mike recommends getting a really good evaluation of your abilities and shortcomings before you start and adding or planning for the addition of people to offset those shortcomings. He also cautions that the engineering entrepreneur may not be good at assessing the abilities of others and suggests help from professionals in this area rather than taking chances. It seems to be difficult for company founders to hire people who have the potential to take over and even become their boss, although that frequently would be the most desirable objective.

Investors and Their Impact

Until now, we have considered the problems of converting from engineering concepts to management concepts and some of the adjustments the engineer needs to make as he launches and develops a business entity. But the biggest shock is yet to come! Having started a small business and having gathered a few kindred and supportive souls around him, we now find our entrepreneur running a little short of money to finance his success. I'll never forget my first really successful year when I had a nice profit on the balance sheet but, because my cash was tied up in Inventory and Accounts Receivable, I had to borrow money from the bank to pay the corporate income tax due. But that is not the real shock that still awaits our hero.

Taking "INVESTORS" into the company is when our engineer-cum-businessman will really learn about business! After what may be one or two years of risking his home, his savings, his wife and family and his reputation, the fledgling corporate executive will probably be requested to sell himself and his company to potential investors. He approaches them confident of the future success of the enterprise (for hasn't it already survived the dangerous start-up phase?) and expects these guardians of someone else's money to leap at the chance to capitalize on his hard work and innovations. For this opportunity, he also expects them to be satisfied with a small percentage of the ownership in exchange for a significant infusion of capital. Perhaps he has sought some counsel in this regard and recognizes that he may have to relinquish a significant portion of the company, but after all, will retain control to ensure its continued success.

If you were to ask a well-established venture capital company what its greatest concern is when contemplating investment, they will probably tell you it is the management team that is already in place. Is it a well-rounded team? Will they have to insist on the addition of some key people that-somehow or other-the enterprise has existed without to this point in time? Or worse still, will they have to insist on the replacement of someone, perhaps the founder? A lot will depend upon the individuals involved in the company and how far it has developed. If I had to do it again, I would like to start from scratch with someone else's money. When negotiating with potential investors at that stage, you get a better idea of what they think your ideas and capabilities are worth rather than after the start-up phase when all of your mistakes are right there in black and white for all who want to see. The problem, of course, is that if this is your first business activity, then you have no track record and and you can only be evaluated on your potential. But as we all have learned over the years, some things look better in theory than they turn out to be in practice.

All thing considered, I believe that bringing investors into a new business venture as early as possible is the best way to go. It gives you some very experienced help when you need it most. Having one or two seasoned venture capitalists on your Board of Directors is a very valuable asset. They will be more realistic about your company's potential and future. They may also be able to put in more money as it is needed, or introduce you to other investors who are likely to be interested in your company at a particular phase of its development.

No matter how realistic you think you may be about the value of your company, it is probably only worth that much to you. Trying to find an investor who agrees with your evaluation is harder than finding a small coding error in ten thousand lines of programming. The investment world has its own rules, all well established and justified, but heartless in their application. It has to be that way! So brace yourself and prepare for the shock, but ease the blow by seeking other professional advice in advance. Developing a successful presentation to potential investors takes a lot of specialized effort and time. This is the kind of effort that may not be your strong suit and you may also lack the time to do it properly. Again you may need professional help.

Conclusion

The purpose of this article is to examine the problems faced by engineers when they contemplate becoming businessmen. We have identified the basic problem, conversion from a technical, factually-oriented kind of activity to the guesswork and "gut-feel" realm of the business world. Of course, if you can place yourself in a large organization with market research facilities, a staff of lawyers, financial specialists and personnel officers, then you may not find the change such a shock. You may find yourself evaluating detailed reports that make the answers to the problems of business more obvious. Working in this kind of environment may be just right for you. But, on the other hand, if you are a highly motivated individual that likes to be in control of his own destiny, then launching your own enterprise is probably the most exciting and demanding activity you will ever undertake. But don't forget that you will have a lot of learning to do, some of which may result in costly mistakes.

Being of a logical, technically-oriented mind, how does one make a successful conversion to the world of business. Firstly, know your limitations! Talk to people who will be honest with you and tell you if they think you lack some vital entrepreneurial capabilities. Take some courses, those that will give you an insight into business procedures. Talk to individuals who have made the transition and ask what made it difficult for them. Talk to your bank manager about loans, personal guarantees, interest rates and mortgages. Talk to a lawyer about incorporation, fiduciary duties, directorships, and corporate law. Talk to a Chartered Accountant about financial ratios, return on investment, leverage and TAXES! Talk to your spouse about long hours of work and low levels of income. And talk to yourself about commitment!

I have attended a number of trade conventions in Las Vegas and have never succumbed to the temptation of slot machines or gaming tables. I do not consider myself a gambler. I was therefore rather surprised when an old friend told me that I was the biggest gambler he knew. Strangely enough, I had never considered my business activities a gamble, I never expected them to fail! Of course I was aware that there were risks involved, after all, there is no profit without risk, but I was comfortable with that risk and believed the odds were in my favour. So my advice to those with the right characteristics to make the transition from engineer to business person is -go for it! Remember, "nothing ventured, nothing gained" and you may find, as many others have, that the personal rewards are far greater than the monetary ones.

About the Author

Gordon English is a Senior Member of the IEEE and the immediate past Director of the Canadian Region.

After twenty years in a technical role in government operated telecommunications facilities, he founded his own company, Westronic Inc., originally a technical sales organization selling products and systems manufactured by others. In 1980, a manufacturing operation was created that today specializes in Remote Terminal Units used in Supervisory Control and Data Acquisition applications throughout the world. Westronic Inc. is now based in Calgary, Alberta and employs over 100 people there. A subsidiary company has been launched in the United States to pursue the telecom market and a joint venture has been established in Australia to serve that geographical area. Still active on the Board of Directors as its Vice Chairman, Gordon has turned the day-to-day management of the company over to people trained and experienced in the management of a growing manufacturing and marketing enterprise.

IEEE Canada Newsflash

1988 Elections

Wallace S. Read, former director of IEEE Canada and presently President of the Canadian Electrical Association has been elected Treasurer of IEEE. He has also been nominated by the IEEE Board of Directors as a candidate for IEEE President-elect in next year's elections.

Also in this year's elections, Dr. A. (Tony) R. Eastham has been elected Director of IEEE Canada for 1990-91.

Two Awards for Former IEEE Director

Dr. George Sinclair, 1974-75 IEEE Canada Director, has been awarded one of two Manning Merit Awards for achievements in the design and manufacture of antennas and multicouplers. He also received an award from the University of Alberta on October 8 at the celebration of the 75th anniversary of the Faculty of Engineering, for professional achievement in industry. He was the recipient in 1975 of the IEEE McNaughton Gold Medal.

Dr. G. Sinclair

Blaine Hein Starts E-Mail Network and Wins Larry K. Wilson Award

Blaine Hein, University of Manitoba, was awarded the Larry K. Wilson Award at the WCC Student Branch Training Session in Calgary for his work in establishing an E-Mail system within the IEEE McNaughton Centre at his University. This concept is being extended across Canada and it is hoped to link up most of our Student Branches with E-Mail using the no-cost NetNorth network before the end of the year. To hook up your branch, ask your Counsellor to set up a NetNorth account using account name IEEESB. Contact SAC Chairman Gerald Karam at Carleton University for further information or help. His E-Mail address is KARAM@SCE. CARLETON. CDN

IEEE Standards

All IEEE standards are available direct by from IEEE Canada. The complete listing of IEEE Standards is also available. Fax or phone your order or enquiry to IEEE Canada at any time. We stock in Canada and eliminate customs or other import delays. We can arrange courier delivery service.

Micro-Mouse ... Again!

The next Micro-Mouse competition to be held in Canada will be sponsored by the Montreal Section of IEEE on July 15 and 16, 1989. For more information, contact Dr. Michel Fortier, tel. (514) 765-7822, fax (514) 765-8785.

Obituary

We regret to announce the death of Dr. Rudi deBuda, the recipient of the 1988 McNaughton Gold Medal (see September issue of Review). Our condolences are sent to his family.

The *Amethyste* Nuclear Submarine - An Overview

An innovative French design challenges Canadians to review their ideas about nuclear submarines.

by Robert Mustard
Senior Consultant, SNA Canada Inc.
Ottawa, Ontario

What is a "military" submarine? It is, very simply, a pressure vessel that carries a weapon system and that can operate under the sea for an extended period of time. It must be safe and controllable, and provide the domestic and life support needs of the crew.

Why nuclear propulsion? Nuclear propulsion is the only proven technology at this time that allows a submarine to operate independently of surface air for a period of time well in excess of the capability of the crew to operate efficiently. The limit, which is in excess of two months, is generally governed by the amount of food that can be carried on the submarine.

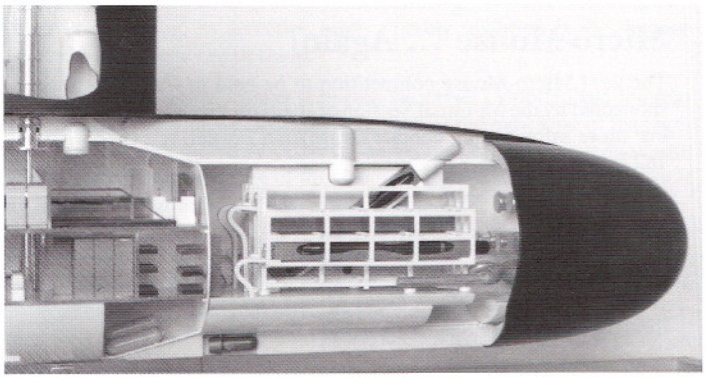
General Description

The *Amethyste* nuclear submarine is divided into three main sections. The forward compartment is devoted to weapon launching equipment and weapon stowage (Figure 1). There are six torpedo tubes and additional stowage for 16 full-length weapons. The weapon launching system uses a water ram discharge and the following types of devices can be launched from the torpedo tubes:

a. wire-guided torpedoes
b. anti-ship missiles
c. mines
d. active and passive decoys

The midships compartments (Figure 2), between the forward compartment and the reactor room, contains the nerve centre of the boat. It can be seen that the operations control room is large for the size of the boat. This section also contains most of the crew accommodation, provisions store rooms, cold rooms, air conditioning rooms, and bays for electronic equipment. The main battery and the diesel alternator are also in this space, remote from the reactor room. It should be noted that this submarine can operate as a diesel electric submarine, its range limited only by the amount of diesel fuel oil carried on board. This area also contains the general life support, recreational and habitability systems and facilities including the galley equipments. For example, these include microwave ovens, VCRs, TV monitors, washers, dryers, stoves, ovens, oxygen generation and CO_2 scrubbing equipment, black & grey water disposal, ablutions and so on, and all the

Figure 1
The forward compartment is devoted to weapon launching equipment.



Some Naval Definitions

SSN: Naval designation for a nuclear submarine

SSBN: Naval designation for a ballistic nuclear submarine

Nuclear Submarines and Arctic Strategy...

The primary function of a Canadian nuclear submarine force, as proposed in a Ministry of Defence White Book tabled in June 1987, is to protect Canadian interests related to national sovereignty and security in the Arctic.

On one hand, Americans refuse to recognize the sovereignty of Canadian Arctic waters and send nuclear-powered submarines armed with nuclear warheads to patrol in those waters. On the other hand, the factual presence of Soviet submarines in the Arctic not only violates Canadian sovereignty as well, these represent a serious threat to our national security and to the safety our population.

It follows that the presence of Canadian nuclear powered submarines in Canadian waters, capable of remaining submerged for extended periods of time and for long distances, constitute a possible means of affirming, if not forcing, the recognition of Canadian sovereignty in the Arctic.

From "Les sous-marins nucléaires"
by André Ferland, Le Devoir, Montreal, October 14, 1988.

Les sous-marins nucléaires et les enjeux stratégiques dans l'arctique...

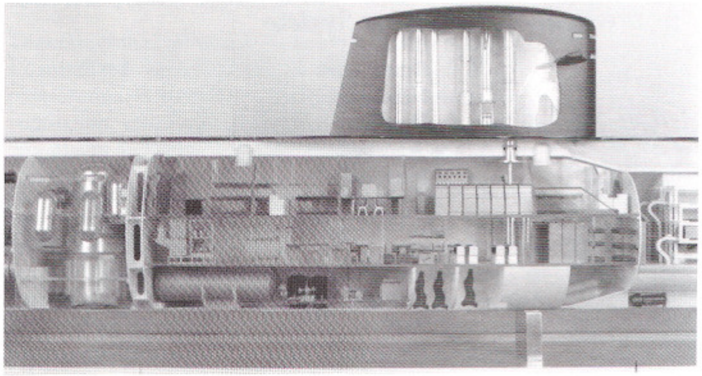
Le rôle d'une flotille de sous-marins à propulsion nucléaire, tel que proposé dans le Livre Blanc de la Défense déposé en juin 1987, est de sauvegarder les intérêts liés à la souveraineté et à la sécurité canadienne dans l'arctique.

D'une part, les Américains refusent de reconnaître la souveraineté des eaux canadiennes dans l'arctique et ils y envoient impunément leurs propres sous-marins nucléaires, porteurs de missiles nucléaires, patrouiller dans ces eaux. D'autre part, la présence factuelle de sous-marins soviétiques dans l'arctique ne contrevient pas seulement à la souveraineté canadienne, elle représente une menace grave pour la sécurité de l'État canadien et des individus qui l'habitent.

La présence de sous-marins à propulsion nucléaire canadiens dans les eaux canadiennes, seuls bâtiments en mesure de couvrir sous l'eau de grandes distances, constituerait donc un moyen d'affirmer et de faire reconnaître la souveraineté canadienne dans l'arctique.

Tiré de "Les sous-marins nucléaires"
par André Ferland, Le Devoir, Montréal, le 14 octobre 1988.

Figure 2
The midships compartment: the *Amethyste* nerve center.



electrical and electronic systems that monitor, control, and regulate the systems as well as the safety and shut down systems.

The nuclear boiler, the main propulsion and electrical generating machinery and the machinery control system are contained in the after compartments, and most of the rotating machinery is grouped in this section well away from the bow sonars.

The pressure hull of the *Amethyste* is made of High Strengh, High Elasticity (HLES) 80 steel. The characteristics of this steel, particularly with regard to the consistency with which the welding results can be repeated and reproduced, and its excellent resistance to corrosion, permit limitless cycles of diving to maximum depth throughout the life of the submarine, and great shock resistance. In addition, the French design concept is to provide maintenance hatches in the pressure hull through which all equipment on board, including the nuclear boiler, can be removed for maintenance without the necessity of cutting and re-welding the pressure hull, thereby risking changing the metallic properties of the steel.

This hatch concept has a major effect on the operational use which can be obtained from the *Amethyste* class submarine. Major refits are only needed at intervals of 60 to 66 months. The duration of these refits is twelve months, a comparatively short refit duration made possible because of the hatches. This remarkable steel for the pressure hull was developed by Creusot-Loire.

Power Plant and Propulsion system

The power plant and propulsion system design can be rightfully regarded as a key point of the overall concept. This is so because it was only through the acceptance of highly innovative solutions that the concept of a small, yet operationally efficient SSN became feasible. The starting point of the design was to ascertain whether it was possible to develop an efficient, safe, and reliable nuclear power plant which would fit into a hull whose diameter had been fixed a priori (7.6 m, corresponding to a three-deck design). Most SSNs and SSBNs have a four-deck arrangement, resulting in hull diameters of about 10 m, whereas a three-deck arrangement makes it possible to have a smaller boat and reduced crew without accepting compromises on either the combat system or the crew accommodation.

Virtually all nuclear-propelled warships currently operational are powered by pressurized water reactors, with water circulation through the reactor and the heat exchanger being ensured by pumps. The CAS48 (Advanced Power Plant Series, 48 megawatt) nuclear reactor developed by Technicatome for the French programme, works with pressurized water, but with a very important difference: circulation of water (primary fluid) through the reactor and the heat exchanger is ensured not by pumps but rather by natural convection, the heat exchanger/steam generator being placed above the reactor inside the same pressure-resistant vessel (which leads to the whole being referred to as "integral reactor").

The CAS48 offers several advantages over conventional solutions: the whole system (nuclear reactor/heat exchanger/steam generator) is much more compact and, in normal operating conditions, the absence of the pump eliminates one of the main sources of radiated noise onboard nuclear-powered submarines. The CAS48 is still fitted with a primary circulation pump, which augments natural convection when maximum power output is needed (in which case the noise caused by the submarine's motion through water would make pump noise irrelevant) or when, under extreme circumstances, the boat takes such an attitude (very heavy list, steep dive or nose-up ascent) as to impair natural convection. If need be, the CAS48 can, thus, work as a "normal" reactor.

The natural-convection reactor has proved so efficient and reliable that the French Navy has adopted it for its new nuclear-powered aircraft carriers and for the new SSBNs, currently under construction - even though these have no specific dimensional constraints. The propulsion machinery is also unique. In conventional nuclear propulsion plants, the steam generated by the nuclear reactor is fed to turbine(s), which moves the shaft(s) through reduction gear(s). The whole is rather bulky, heavy and - what matters more - an unwelcome source of radiated noise; in particular, the reduction gears are quite difficult to effectively "silence". In the *Amethyste* design, the steam is fed to two constant-speed turbines (developed and built by the Thermodyn division of Framatome), each of which drives two alternators (one for propulsion, and the other for ship's services). The current generated by the two propulsion alternators is then fed to a single Jeumont-Schneider electric propulsion motor (actually two half-motors), which drives the seven-blade propeller.

The main advantage offered by the electric machinery configuration is its quietness and flexibility: applied power can be increased from 0 to 100% in less than a minute, the limits on the boat acceleration capability are due to hydrodynamics rather than to the power plant. Additionally, dispensing with the reduction gears eliminates a major source of radiated noise. Smaller boats such as the *Amethyste* require less specific power and thus smaller motors - hence, it is possible to fully exploit the advantages of electric propulsion.

Needless to say, no compromise is accepted regarding safety; on the contrary, nuclear-convection reactors are inherently safer than conventional Pressurized Water Reactor (PWR) designs. The system is no longer critically dependent on the primary coolant pump to distribute the thermal energy given off by the core, and the consequences of a depressurization of the coolant system are notably reduced owing to the elimination of the large-diameter primary coolant loops. (It is even possible to enter the nuclear reactor compartment while the boat is at sea.) In normal operation, both the nuclear reactor compartment and the turbine/alternator compartment are unmanned, and the propulsion is controlled from a control room placed between the turbine/alternator compartment and the electric motor compartment.

Combat system

A fully integrated combat system is an essential part of the submarine. It consists of: the acoustic detection systems, the tactical data handling system, the fire control system, the weapon launching system, the non-acoustic sensor systems and the navigation system.

SAGEM, a major defence contractor, supplies the following non-acoustic and navigation systems to the French Navy:

- the search periscope which includes infrared (IR), optical, gyrostabilized line of sight capability, IR surveillance and Low-Level Light TV (LLTV) capability, "Navstar" antennas, sextant, gyroscopic range finder and Electronic Support Measures (ESM) warning;
- the attack periscope on a non-penetrating mast with gyrostabilized TV, image intensifier and ESM warning;
- an integrated navigation system which uses a dual Minicin INS with high quality Kalman filtering, updated by using GPS Navstar, Loran C and sextant. A doppler sonar speed log also inputs to the system.

Other non-acoustic sensors are of course the radar and external communications. External communications cover the range from ELF/VLF to UHF/SHF, voice and data, covered and clear as appropriate. A fundamental means of communication remains the underwater telephone.

The acoustic detection system is provided by Thomson-Sintra Activités Sous-Marines (ASM) and covers the frequency range from 10Hz to 100kHz. The system can be described as a multifunction multiarray sonar. The large set of arrays used with this sonar are diagrammed in Figure 3. In addition to the arrays shown, there is self-noise monitoring hydrophones and accelerometers and a sound velocity profiling device. The functions defined in Table 1 are performed in the combat system shown schematically in Figure 4. Thomson-Sintra ASM is also responsible for the Tactical Data Handling and Fire Control Systems and the Multifunction Control Consoles (MFCCs) and the vertical plot. There is a significant amount of signal and data processing required in the system. The signal processing requirements are in excess of 2 Gigaflops while the data processing exceeds 50 Mips. Except for the radar (which is used only for safety of navigation) the whole combat system is operated from the seven MFCCs in the control room. Any console can be used for any function and the allocation of operator tasks can be changed at any time as a result of reconfiguration due to changes in the tactical situation, or in case of a failure.

The allocation of the functions depends on the specific operational situation; in general, at action stations, three or four consoles would be devoted to sonar operation (surveillance, detection, classification and spectral analysis, or analysis of own noise), two would be reserved to simultaneously engage four different targets with wire-guided torpedoes (it would be possible to use a single console but it is felt that even a skilled operator probably cannot handle more than two targets simultaneously), while one would be reserved to the tactical coordinator. The overall tactical situation is also displayed on a large vertical command plot.

Under different conditions, a console could be left free as a decision aid for the Commander and, during use of the attack periscope, a console is used to visualize the LLTV imagery. Any given console can be allocated any given function but it is suggested that the first three to four consoles (counting from the bow) should always be reserved for sonar operation, in that they are placed in a "quiet" corner which favours listening.

The displays available on each console (2 x 19" high resolution colour displays, pictures in memory permanently updated) can be called at any time by the operators of other consoles. Flexible allocation allows the display of:

- sonar functions (broadband, narrowband, sonar interception);
- sonar localization;
- classification analysis;
- tactical aids;
- optronics display (infrared and low light level TV camera);
- ESM information;
- target engagement;
- navigation;
- various support function such as:
    - performance prediction
    - noise monitoring
    - system configuration
    - fault localization
    - recording/play-back
    - training

In the port forward side of the control room is the centralized control system. This fully digital, triply redundant self-monitoring system allows a single operator to control course, depth, trim, compensation and propeller rpm. Normally, the submarine is steered in the automatic mode, that is to say, with course control under the majority logic of three computers with headings called up by the Officer of the Watch. (This mode of steering is currently used about 70% of the time). The "normal manual" mode receives plane angle inputs electronically directly from the helmsman joystick and valve actuators and closed loop feedback set plane or rudder angles.

In the "emergency manual" mode, the hydraulic control valves are actuated mechanically by use of the emergency control levers. Feedback is not closed though plane and rudder angle indication are still functional.

Diving Safety

Diving safety is based on the following four principles:

- Separation of function between systems
- Redundancy of equipment and system isolation devices
- Reliability and conservative improvement steps
- Centralized command and control

All salt water systems are separate and dedicated by compartment, ballast,

Table 1 - **Operational Functions**

DETECTION	***Sonar System***
	• Broadband • Narrowband • Demon • Transient • Intercept • Active • Hostile Weapon Detection with Automatic Alarm
	Others (non-acoustic sensors) • Radar • ESM Analysis • Periscopes Data Analysis
LOCALIZATION AND TRACKING	***Sonar System***
	Tracking on: • Broadband • Narrowband • Demon • Intercept • Active • Hostile Weapon
	Ranging: • Direct Passive Ranging • Active Ranging • CMA
	Others (non-acoustic sensors)
Data Base Computer-Aided Procedures	
CLASSIFICATION	***Sonar System***
	• Spectral Analysis Lofar and Demon • Pulse Analysis • Audio Listening and Analysis • Stored data comparison
	Others (non-acoustic sensors)
TACTICAL SITUATION ELABORATION	• Sonar Data management • Non-acoustic sensors data management • Multisensor association and fusion • Tactical summary • Tactical situation display • True motion tactical situation display • Communication & Intelligence
ENGAGEMENT	• Tube/weapon/target assignment • Presetting the weapons • Weapon launching and guidance
SUPPORT FUNCTIONS	• System initialization and management • Environmental prediction (Sound velocity measurement and sound ray analysis - Performance prediction) • Self Noise Monitoring • Underwater communications • Recording • On-board training • Performance Monitoring and Fault Localization (PM/FL) (provides maintenance facility) • Reconfiguration facilities

bilge, machinery cooling, etc... and all hull penetrations are guarded by skin and guard valves, each valve capable of local and remote operation.

The condition of all systems is monitored and controlled at a centralized console in the control room, just aft of the control console, including ballast, trim, hydraulic systems, ventilation, electricity generation and distribution (both propulsion and ships services) and the nuclear plant.

Electrical distribution, both AC and DC, is effected through two distribution centres, one forward and one aft. Each distribution centre is supplied by one AC generator, generated DC, and both batteries. The submarine is fitted with two battery banks, the main battery for emergency propulsion and an emergency battery for nuclear plant safety. Main propulsion, emergency propulsion and certain critical services are powered by DC motors, the remainder of the auxiliaries and hotel services are supplied by 60 Hz AC.

It should be noted that a sufficiency of DC battery power is available to start or re-start the nuclear power plant from cold.

On the port after port of the control room is the navigation position. Just aft of the control room is the communications room.

Figure 3 The combat system

Finally, one more sub-system should be mentioned. This is the interior communication system. Télécommunications, Radios électriques et Téléphoniques (TRT), a French company, supplies a fully integrated system that covers all the voice telephone and Public Address (PA) requirements of the submarine and is also integrated into the exterior communications system.

Conclusion

It is interesting to note how all the pieces of the "design puzzle" fit together.

A small hull was specified to start with, and this was made possible by the development of an innovative nuclear reactor. Consequently, the small dimensions made it practical to go further and adopt electric propulsion. Additionally, the whole is consistent with reduced crew.

The nuclear/electric propulsion plant as adopted on the *Amethyste* offers the following advantages:

- Smaller dimensions, making it feasible to have a smaller boat without accepting compromises on either the combat system or the crew accomodation;
- Low radiated noise level (no reduction gears, no primary pump noise under most operating conditions);
- High flexibility and readiness in answering to changes in applied power.

Some Highlights From the French Proposal

In the construction and commissioning of 12 nuclear-powered submarines based on the French *Amethyste* design, a realistic scenario is to assemble the vessels and their nuclear propulsion systems in Canada starting with vessel number two. From then on, the extent of Canadian participation in the supply of equipment will rise rapidly over time. Under this scenario:

- 92% of shipyard work will be done in Canada.
- 78% of the equipment will be sourced in Canada,
- 70,000 to 80,000 person-years of employment will be generated.
- Employment will be in mostly skilled categories and will cover industrial sectors as diverse as: shipbuilding, metal fabrication, general manufacturing, electronics, optronics, etc.
- The overall program will have more than 80% Canadian content.

A broad comparison of cost factors and pricing practices in France and Canada showed that, after a brief period of training by Canadian industry to achieve the appropriate skill level, it will prove cost-effective to assemble vessels and manufacture the equipment in Canada as opposed to France, enabling the cost to remain within the $8 billion envelope designated for Canada's nuclear submarine program.

The memorandum of understanding between France and Canada provides for full, unfettered transfer of *Amethyste* technology to Canada.

(From an independent economic study prepared by Stevenson, Kellog, Ernest & Whinney).

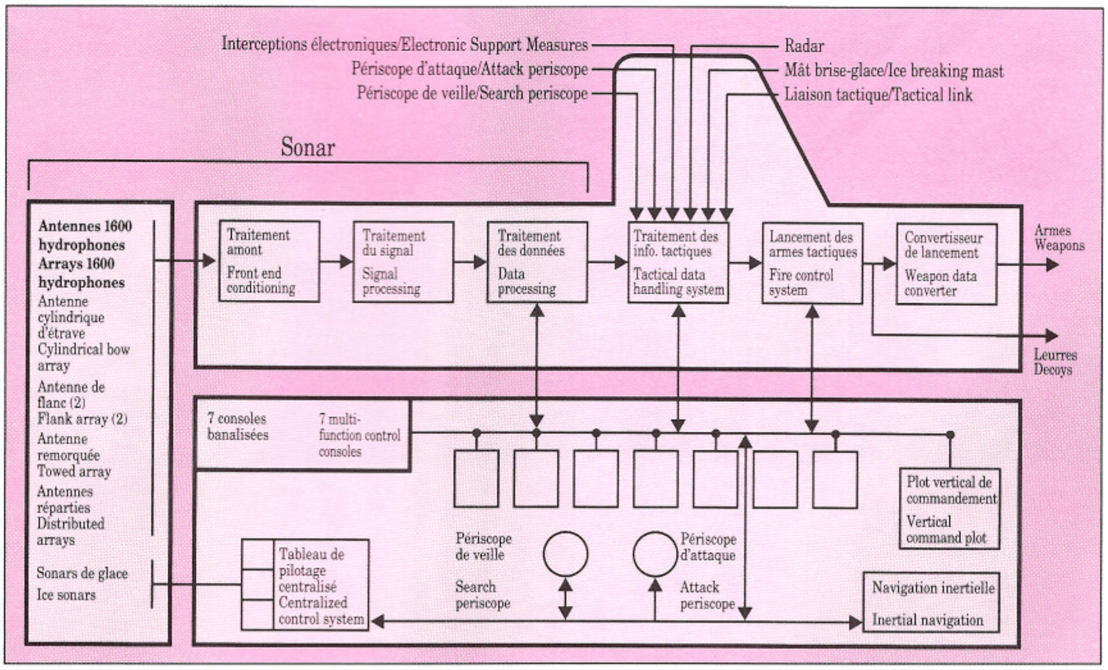


Figure 4 Combat system: functional description

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