Report of the National Advisory Panel on Advanced Industrial Materials

Strategies and Actions for the Adoption of Advanced Materials in Canadian Manufacturing

1993

Presented to the
Minister of Industry
December 1993

Industry Canada Industrie Canada

Canada

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Advanced Materials in Canadian Manufacturing

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DEFINITIONS

Certain terms used in this report are defined as follows:

Advanced Industrial Material (AIM): An emerging material having the following characteristics: its properties are still being optimized, its uses are expected to expand and its cost will probably decrease as its use is expanded.

Design: A procedure of synthesis that creates a process and/or product to meet an identified need. Obviously creative approaches to improving products and/or processes are in the same category.

Manufacturing: The transformation of materials into useful products (including intermediates).

Technology: The application of scientific and engineering knowledge to design and manufacturing.

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Aussi disponible en français sous le titre *Rapport du Comité consultatif national sur les matériaux industriels de pointe : Stratégies et actions à mettre en œuvre pour inciter les fabricants canadiens à adopter les matériaux de pointe, 1993.*

Transmittal Letter to the Minister of Industry

On behalf of the members of the National Advisory Panel on Advanced Industrial Materials (NAPAIM) and the numerous people and organizations with whom we have consulted, I am pleased to present the panel's report on Strategies and Actions for the Adoption of Advanced Materials in Canadian Manufacturing.

The focus of the NAPAIM work plan has been on creating a fertile field for the greater use of advanced materials and related technologies, and product innovation by improving the availability of:

- conceptual skills — in design, product and process engineering
- applied skills — in production techniques, process implementation as well as product and process optimization
- materials technology — defining what materials are needed, what materials are available and what materials need to be developed
- money — for attracting and rewarding the time and dollar investment required to incorporate new materials and processes to create competitive products in Canada.

The panel members have identified barriers which impede the development and application of advanced industrial materials (AIM) and the diffusion of AIM knowledge. They have also developed recommendations to overcome the barriers and implementation plans to effect the necessary change. These form the basis of this report.

The recommendations have been developed for three specifically targeted areas, namely, university education, technicians/technologists education, and the diffusion of AIM knowledge to the manufacturing sector.

The NAPAIM report is oriented toward action — action that is necessary to foster and support a climate of innovation in Canadian product and process design.

Implementation of the recommendations is viewed by the members as necessary to fulfilling our mandate and to effecting change. We have sought out and obtained the participation and consensus of the various stakeholders regarding implementation of the recommendations. Each recommendation, therefore, sets out the necessary action and the stakeholder responsible for implementation.

The Next Steps

The current mandate of NAPAIM presents three areas of activity to be pursued subsequent to the acceptance of this report:

- to manage the implementation of the recommendations in this report
- to examine and recommend solutions to demand-side issues affecting AIM
- to investigate and recommend appropriate measurements and benchmarking methods to assess how Canada's competitive position in the world market can be, and is being, enhanced by AIM use.

NAPAIM's goal over the long term is to integrate the demand-side and supply-side elements of the AIM market to support the continuous technology development and innovation required to maintain Canadian industries' competitiveness. The actions set out in this report are the first steps to achieving our mandate. We need to ensure, however, that these next steps are also carried out to fulfil our role.

As a means of ensuring that the recommendations of this report come to fruition, a shared commitment by business, research and academic communities as well as governments at various levels is essential. Beyond this, however, the public at large must come to appreciate and understand the value of advanced industrial materials and technologies to Canada's competitiveness and ultimately to our nation's economic and social well-being.

Our members are committed to a continuing role in this field to improve Canadian competitiveness. We present this report with the intent to continue, with your approval and support, to implement our recommendations and to deliver on other aspects of our mandate. To achieve the goals set out in our mandate and as defined in this report, we need the firm, public endorsement of the federal government to pursue the implementation steps we have recommended.

Yours very truly,

Alex Taylor
Chairperson
National Advisory Panel on
Advanced Industrial Materials

Contents

Glossary of Acronyms and Abbreviations

ACCC	- Association of Canadian Community Colleges
AIM	- advanced industrial materials
AUCC	- Association of Universities and Colleges of Canada
BCIT	- British Columbia Institute of Technology
CANMATE	- Canadian Manufacturing Advanced Technology Exchange
CCDA	- Canadian Council of Directors of Apprenticeship
CCPE	- Canadian Council of Professional Engineers
CHEF	- Corporate-Higher Education Forum
CISTI	- Canada Institute for Scientific and Technical Information
IRAP	- Industrial Research Assistance Program
MetSoc	- Metallurgical Society of the Canadian Institute of Mining, Metallurgy and Petroleum
METTNET	- The Materials Engineering Technology Transfer Network
NABST	- National Advisory Board on Science and Technology
NAIT	- Northern Alberta Institute of Technology
NAPAIM	- National Advisory Panel on Advanced Industrial Materials
NCDEAS	- National Committee of Deans of Engineering and Applied Science
NRC	- National Research Council Canada
NSERC	- Natural Sciences and Engineering Research Council of Canada
OAA	- Ontario Association of Architects
R&D	- research and development
SAMPE	- Society for Advancement of Material and Process Engineering
SMEs	- small and medium-sized enterprises
SPE	- Society of Plastics Engineers

Executive Summary

The National Advisory Panel on Advanced Industrial Materials (NAPAIM) is currently mandated to identify national strategies that will accelerate the development and application of advanced materials and technologies which are needed to strengthen and improve the international competitiveness of Canadian industry. The products and processes identified under the broad area of advanced industrial materials (AIM) are considered by most industrial nations, Canada included, as strategic and enabling technologies.

Advances in the development and application of advanced materials provide Canadian manufacturers with opportunities to lower costs, develop new products, improve product performance and create entirely new industries. Canada, however, lags behind other developed countries in the application of AIM. Countries such as Japan, the United States and many European nations, for example, use AIM more than we currently do. To be more competitive, Canadian industry must focus on innovation by acquiring, adapting and applying AIM to a much greater degree in order to make the best use of materials in our products and processes.

In the period since the commencement of our work in 1990, our members, with the involvement of senior-level stakeholders, have developed recommendations in the areas of critical importance to the use of advanced materials and processes in achieving competitive advantage for Canadian manufacturers.

Our recommendations propose actions to reward innovation among Canadian manufacturers and to improve the supply of people, skills and information which will permit Canadian companies to develop innovative design capabilities and incorporate new advanced materials and processes.

Summary of Mandate

The NAPAIM mandate is focused on providing advice and recommendations regarding the use of advanced materials, advanced processing methods and related technologies to improve the competitiveness of Canadian industry. This advice is to focus on:

- national strategies and plans to accelerate AIM development and application
- materials development and application priorities
- needs and priorities for university research, infrastructure and training
- needs and priorities for information exchange and joint planning, and mechanisms to encourage such exchange
- actions required of the private sector to increase capabilities of resource and manufacturing sectors to effectively exploit opportunities
- mechanisms to promote initiatives to provide the needed market intelligence, technology, marketing and management services
- government policies and their impact on the climate for industry investments
- priorities and mechanisms for international collaboration.

Our efforts over the past two years, as directed by our mandate, have been:

- to identify the barriers which impede the effective use of advanced materials and processes
- to identify the groups and persons, including industries, associations, institutions and governments, with influence over these barriers
- to determine, with these stakeholders, the actions required to break down these barriers and to develop world-leading capabilities in AIM use and application
- to establish a process to implement these actions through the activities of the stakeholders.

The NAPAIM members formed three working groups to address issues in the following areas:

University Education: to assess the roles and functions required of the university community to produce engineers aware of and skilled in materials assessment and applications in product/ process development.

Technicians/Technologists Education: to assess the roles and functions required of the college community and industry to produce people with manufacturing expertise who are aware of and skilled in materials assessment and applications in production processes and product modifications.

Diffusion of AIM Knowledge to the Manufacturing Sector: to assess the financial and practical ability of manufacturers to introduce new materials and processes in products as well as the roles and functions required of the various stakeholders to increase the awareness of and access to AIM information channels.

These working groups have undertaken the following processes:

- identified the broad groups of stakeholders in these areas
- consulted with these stakeholders to define the barriers which impede the greater use of AIM
- developed recommendations on how to overcome these barriers
- consulted again to obtain the stakeholders' consensus and involvement in implementing the NAPAIM recommendations.

Panel members have actively networked, consulted and built consensus on the recommendations and implementation action items, as outlined in the reports. At round table sessions convened for each working group, key senior-level stakeholders from the public and private sectors, management and labour, scientists and academics as well as industry and professional associations provided their input to the reports and their concurrence with the recommendations.

The recommendations succinctly outline what needs to be done, suggest how it might be accomplished and identify those stakeholders responsible for action. In most cases, we have identified specific actions which will assist stakeholders in implementation. More importantly, however, the reports contain suggestions for follow-up activities to monitor and ensure that the recommendations are implemented and thereby achieve our mandated objectives.

The following paragraphs provide a very brief overview of the three reports, which make up the body of this document.

Report on University Education

The Report on University Education recommends changes to engineering education in Canada to provide graduates with the design and materials tools needed today by an engineer entering practice, and to provide the industrial communities with the engineers they need to compete in today's market.

The report provides a course of action to allow engineering students to acquire the appropriate awareness, knowledge and understanding of materials and materials application as well as the ability to translate advances in AIM into economic gain by applying those materials in the design of new products and processes. The report recommends that curriculum changes take place whereby design is taught more widely and with a greater emphasis on its broad role in the business process, and that better instruction be provided respecting the properties and selection of materials. Professional Master's programs in industrial materials that cater to the aspiring materials practitioner or researcher are also recommended.

The report also states that for the recommended changes in engineering education to be effective, it is also in parallel necessary to adequately reward faculty members and to develop closer relationships between the faculty members and industry officials. The panel recommends that teaching and interaction with industry be rewarded in the same fashion as research achievements, that the Natural Sciences and Engineering Research Council of Canada (NSERC) adjust specific grant programs, that mechanisms be developed to ascertain the needs of industry and that a climate be established within the university whereby faculty members are encouraged to interact with industry. A number of recommendations and how-to's are set out in these regards.

Report on Technicians/Technologists Education

The Report on Technicians/Technologists Education concludes that there is a need for broadened general education and sound generic skills. Students must also be able to measure their specific technical skills against international benchmarks. The report recommends that courses be developed to provide a common set of communication, numeracy and technical skills, and that at least one materials course be mandatory. The report further recommends that national standards and a consistent accreditation process be developed to permit mobility of the graduates across the provinces.

The report notes that one of the most positive approaches to the introduction and diffusion of AIM is to collect a select group of college technology programs into centres of specialization. These centres would also have an expanded mandate to become world leaders in training with certain technological specialties.

The report emphasizes the need for instructors to remain current in both their knowledge and skills, and for the establishment of formal consulting and partnership mechanisms with industry. Underlying all of these is the need for a national campaign to promote apprenticeship and technicians/technologists education in Canada to highlight skilled trades as attractive occupations.

Report on the Diffusion of AIM Knowledge to the Manufacturing Sector

The Report on the Diffusion of AIM Knowledge to the Manufacturing Sector emphasizes that the recent adverse business climate has had an inhibiting effect on the rate at which new technology, including AIM, is incorporated into Canadian manufacturers' operations, despite the strong motivation to reduce costs and develop more competitive products. The report recommends that the federal government review income and other tax mechanisms, with the ultimate goal of rewarding successful product and process innovation and commercialization, rather than merely subsidizing research risks.

The report also emphasizes the value of extensive networking that delivers timely and appropriate information, knowledge and expertise to inquiring small and medium-sized enterprises (SMEs) in the manufacturing sector. Networking is the area where most AIM awareness gains and subsequent technology adoption are achieved. It also points out that industry associations, professional associations, SMEs and governments will achieve much more by working more closely together on diffusion activities.

The panel members have developed a number of specific recommendations related to these areas of focus. The majority of the NAPAIM recommendations will also require buy-in and support by provincial governments and associations as well as by the federal government and the national stakeholders identified. The implementation plans of the NAPAIM working groups have identified and incorporated provincial stakeholders and will bring in the provincial governments with federal support, as necessary.

To be internationally competitive, a national commitment to excellence in materials and processing technologies is essential among manufacturers, supporting institutions and all levels of government. A great deal remains to be done. This report, in its components, presents the NAPAIM recommendations and actions we believe will put us on the road to achieving these objectives.

NAPAIM Mandate

The Order in Council creating the National Advisory Panel on Advanced Industrial Materials gave the panel the following Mandate:

"The Panel shall advise the Minister with respect to:

(a) the development of national strategies and plans to accelerate the development and application of advanced materials, advanced processing methods and related technologies, in order to maintain and strengthen the international competitiveness of Canadian industry;

(b) advanced industrial materials technology development and application priorities for Canada;

(c) needs and priorities for university research, infrastructure and training that are essential to support the industrial exploitation of advanced materials technologies;

(d) needs and priorities for information exchange and joint planning among scientists, engineers and industrialists and mechanisms to encourage such exchange and planning;

(e) actions that should be taken by the private sector to increase the capabilities of the resource and manufacturing sectors to effectively exploit opportunities created by advances in materials technologies;

(f) effective mechanisms for promoting initiatives to provide market intelligence, technology and marketing and management services needed to foster the competitiveness of Canadian companies;

(g) government policies and their impact on the climate for industry investments in materials-related research, applications development and commercialization;

(h) priorities and mechanisms for international collaboration in materials science and technology; and

(i) such other matters as the Minister may request."

Listing of NAPAIM Recommendations

Report on University Education

Recommendation 1
Within the undergraduate curriculum, design should be taught more widely and with greater emphasis on its broad role in the business process, including entrepreneurship, and on its broad interface with all engineering disciplines.

Recommendation 2
The Natural Sciences and Engineering Research Council of Canada, through its panels, should adjust its research, strategic and collaborative grants in favour of engineering faculties who focus their research on design and synthesis and who interact with industry.

Recommendation 3
Each university should adjust its reward system for engineering faculty to recognize teaching, interaction with industry and competence in design and materials on an equal footing with research achievements and specialist knowledge.

Recommendation 4
Each faculty of engineering should establish a mechanism for ascertaining the needs and expectations of those industry sectors which absorb the majority of graduating students or which are most closely aligned with the technical specialties of the faculty. Where practical, this should be done on a local basis, and should include industry's need for continuing education in materials technology.

Recommendation 5
Each faculty of engineering should establish a climate in which faculty members are encouraged to interact with industry by seeking industrial experience through sabbaticals, or by consulting, or by collaborative research and development. Industry practitioners should be encouraged to join the faculty on a full-time or adjunct basis.

Recommendation 6
Within the undergraduate program, all engineering students should have (a) required general instruction on the properties and selection of materials; and (b) access to more detailed instruction on materials appropriate to their chosen discipline and electives.

Recommendation 7
Graduate programs in materials should cater to the aspiring materials practitioner as well as to the aspiring researcher. Professional Master's programs in industrial materials should be established at appropriate universities.

Recommendation 8
Initiatives should be developed to increase the understanding of the role of materials by all parties to the process of university education, including the establishment of a standing committee of long-term stakeholders.

Recommendation 9
Sets of guidelines should be established for (a) the curriculum changes proposed in Recommendations 1, 6 and 7; and (b) the cultural, climatic and procedural changes proposed in Recommendations 3 and 5.

Report on Technicians/Technologists Education

Recommendation 1
Colleges should develop foundation courses that will provide all graduates with a common set of basic communication, numeracy and technical skills.

Recommendation 2
College programs in technology-related disciplines should be structured to include at least one required course in materials within the chosen technology program curriculum.

Recommendation 3
The Association of Canadian Community Colleges in cooperation with the Canadian Council of Technicians and Technologists should establish formal consultative mechanisms with industry for purposes of updating community college curricula to include materials-related programs.

Recommendation 4
Colleges should provide their teachers with the opportunity to update their technological knowledge by permitting them to attend short courses offered by the universities or other external sources (e.g. consultant seminars) in the emerging subjects such as new materials.

Recommendation 5
Colleges should reward teachers who direct their efforts to teaching excellence and dynamic interactions with industry in new areas such as advanced materials.

Recommendation 6
Colleges should expand cooperative education by including AIM-related disciplines in their programs.

Recommendation 7
A selected group of college technology programs should be combined into centres of specialization with an expanded mandate to become world leaders in training for certain technological specialties, including materials-related specialties.

Recommendation 8
Business, labour and governments, in cooperation with secondary and postsecondary learning facilities, should undertake a national campaign to promote apprenticeship in Canada as a proper and desirable form of advanced education and skills training.

Recommendation 9
Governments at all levels should support industry by assisting industry associations in their efforts to promote the image of skilled trades as an attractive occupation.

Recommendation 10
The Canadian Council of Directors of Apprenticeship, in close cooperation with industry, should update and upgrade the program content of the key trades that support AIM so they reflect a new AIM technology.

Recommendation 11
The apprenticeship in technology programs should be connected with universities (engineering), and advanced degree possibilities should be offered, with credit being given for technology courses.

Report on the Diffusion of AIM Knowledge to the Manufacturing Sector

Recommendation 1
Innovation should be rewarded through a significant advantageous tax treatment for profits derived from the manufacture of Canadian designed and developed products. This action should be designed to be cost-neutral within the tax system.

Recommendation 2
Industry Canada and the National Research Council Canada should develop a compendium of all recipient firms under various Industry Canada programs as well as the Industrial Research Assistance Program, categorized by type of material used, as a starting point for a list of prospective small and medium-sized enterprises who would be candidates to use an expanded country-wide network to acquire new AIM knowledge.

Recommendation 3
The national materials network, which originally comprised representatives of Industry Canada regional offices and sector branches in Ottawa, recently expanded to include officials of the Industrial Research Assistance Program. The network should be further expanded to include provincial government and private industry representation, with the objective of assisting with identification of recipients of AIM knowledge and publicizing successful achievements based on AIM.

Recommendation 4
One or more professional associations will be approached to help disseminate AIM knowledge with the help of selected firms that supply AIM and to encourage these associations to seek closer working relations with industry associations.

Recommendation 5
The Canadian Manufacturing Advanced Technology Exchange and the Canada Institute for Scientific and Technical Information databases that currently provide AIM knowledge to small and medium-sized enterprises should be improved by adding an inventory of people with AIM knowledge and making the databases more user accessible. A greater focus on materials information should be stressed.

Recommendation 6
A larger portion of the Natural Sciences and Engineering Research Council of Canada's Targeted Grants for University Research should be earmarked for projects involving industrially relevant problems using AIM. Similarly, industry recipients of support from various federal government programs should be encouraged to seek out practical university support for their technical problems.

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Report on University Education

Introduction

The National Advisory Panel on Advanced Industrial Materials (NAPAIM) reports to the Minister of Industry Canada; its objective is to identify national strategies to accelerate the development and application of the advanced materials and related technologies needed to strengthen the international competitiveness of Canadian industry. The Working Group on University Education was formed within NAPAIM to focus on the teaching of materials and materials-related subjects in Canadian universities.

To be competitive, Canadian industry needs to make the best use of materials, including advanced materials, in its products and processes. In order to achieve this, Canadian engineering students need to acquire appropriate awareness, knowledge and understanding of materials and their application. There is also a need for more specialists who can work in industry to ensure the development and application of advanced materials.

The report identifies four major barriers to meeting these needs: inadequate teaching of design, insufficient interaction between engineering faculty and industry, inadequate teaching of materials, and a lack of ability in oral and written communication.

Nine recommendations are made for overcoming these barriers. The principal focus is on the better teaching of design as the context within which materials are selected and used, recognizing that the relationships among design, manufacturing processes and materials are key to successful product development. Better teaching of design requires changes to the reward systems within the university so as to recognize teaching equally with research, to recognize the importance of faculty interaction with industry, and to recognize research based on synthesis as well as analysis. Corresponding changes to the priorities for awarding research grants are also required.

More and better teaching of materials is needed at both undergraduate and graduate levels. At the undergraduate level, all engineering students should receive general instruction on materials and should have access to more specialized instruction on materials appropriate to their chosen discipline or electives. Graduate programs in materials should cater to the aspiring materials practitioner as well as to the aspiring researcher. Professional Master's programs in industrial materials should be established at appropriate universities.

It is important that the essential role played by design and materials in Canada's economic well-being is better understood by all those involved with university education: university administration, faculty, students, industry, and the providers of funds for education and research.

The report contains specific proposals for the implementation of the recommendations, including the identification of those individuals or bodies who can bring about the recommended changes.

The next two pages highlight key suggestions from the report. These are grouped according to the change agent/stakeholder whose action is suggested.

Key Suggestions

Faculties of engineering should:

- embed the teaching of design throughout the engineering curriculum, explaining how design is carried out in industry, including the role of teams, with faculty promotion linked to participation in this process
- in consort with their universities, hire and reward faculty on the basis that industrial experience has parity with academic experience (postdoctoral fellowship or faculty membership) and that design achievements have parity with the publication of refereed papers, with promotion contingent on continuing accumulation of industry-related experience
- include at least one required course in materials in the undergraduate curriculum, designed to give an appreciation of the materials available, their role in new products and processes, and how further knowl-

edge about materials and their application may be acquired (many universities are already doing this, but more must be done)
- offer a professional Master's degree in materials at appropriate universities across Canada, to include both instruction in the use of materials in design and a materials project to be undertaken in industry
- offer extension courses in materials technology
- improve the competence of engineering graduates in oral and written communication
- seek out opportunities for collaborative research with industry.

Universities should:
- encourage and support faculties of engineering in implementing the above changes
- encourage multidisciplinary and multifaculty programs in materials at both undergraduate and graduate levels, the graduate programs to be aimed at both the researcher and the practitioner
- encourage a broader recognition by the university community — administration, faculty and students — of the role of materials in the design of new products and industrial processes and in the economic well-being of Canada.

Provincial governments should:
- provide increased and targeted financial support to those universities and faculties which are implementing the changes recommended above, recognizing the additional costs incurred in the effective teaching of design and materials
- make ongoing financial support conditional on a record of steadily increasing links between faculty and industry.

The federal government should:
- actively support and encourage the Natural Sciences and Engineering Research Council of Canada (NSERC) and other government agents in their implementation of the changes recommended in this report
- encourage recipients of government contracts to use more collaborative research with universities
- sponsor a national design competition, preferably through the National Research Council Canada (NRC).

NSERC should:
- through its panels, adjust its research, strategic and collaborative grants in favour of engineering faculties who focus their research on design and synthesis and who interact with industry
- increase funding to university/industry research collaborations
- clarify instructions to the grant selection committees about the importance of researchers' maintaining contact with industry through sabbaticals, contracted research and consulting.

Industry should:
- contribute to the resources needed for the teaching of design — adjunct professors, materials practitioners, laboratory access, case studies and financial support
- provide similar support for the teaching of materials engineering and materials science
- actively recruit faculty on sabbatical and involve them in industrial design problems
- support professional Master's programs by accepting students into materials projects and providing for their financial support and professional development
- encourage faculties of engineering to provide extension courses in materials technology
- seek out opportunities for collaborative research with universities.

Need

To be competitive, Canadian industry needs to make the best use of materials, including advanced materials, in its products and processes. Canadian universities and industry have made significant advances in the research, development and application of new materials and processes.

In order to translate these advances into economic gain, engineering students need to acquire appropriate awareness, knowledge and understanding of materials and their application, including the broad spectrum of materials which are available from outside Canada. This will provide industry with engineers who recognize the wide range of available materials and who are able to apply them in the design of products and processes, whether in existing enterprises or in the creation of new industries.

There is also a need for more highly qualified specialists to work in industry to ensure the development and application of advanced materials, or to conduct research into new materials and processes.

Barriers

The working group identified four major barriers to meeting these needs.

Inadequate Teaching of Design: Design is the context within which materials are selected and used. The critical relationship between design, materials selection and manufacturing processes is not always recognized and is often poorly taught. In contrast, this relationship is well recognized in Europe. Reinforcing this barrier is a faculty reward system that gives more recognition to research than to teaching or to interaction with industry, and more recognition for the publishing of analytical papers than for engaging in synthesis and design activities.

Insufficient Interaction between Engineering Faculty and Industry (particularly the teaching of design): The inadequacy of industry involvement with the engineering education process — in both the teaching of engineering and collaborative research with universities — has resulted in a failure to define what industry needs from the universities. There is also inadequate understanding by many engineering faculties of the design process in industry.

Inadequate Teaching of Materials: This affects both generalist engineering students and aspiring materials practitioners. The teaching of materials must include information on the properties, selection and application of both new and conventional materials as well as how to design new materials which can be optimized for their application.

Lack of Ability in Oral and Written Communication: This lack of ability reduces the effectiveness of engineering graduates.

Discussion and Recommendations

Teaching of Design

Design is the context within which materials are selected and used, and the relationship between design, manufacturing processes and materials are key to successful product development.

Recommendation 1

Within the undergraduate curriculum, design should be taught more widely and with greater emphasis on its broad role in the business process, including entrepreneurship, and on its broad interface with all engineering disciplines.

An effective undergraduate design program should have the following characteristics:

- instruction in design and synthesis throughout the curriculum, including the first year, and also in the role of analysis in the design process
- instruction about the overall new product development process within which design will take place in industry, particularly the growing use of multidisciplinary teams
- teaching of all specialist subjects in the context of the design process in which they will eventually be used
- emphasis on the role of materials selection and the analysis of materials performance in the design process, identifying the means available for acquiring the necessary knowledge
- use of competitive design projects involving multidisciplinary teams throughout the curriculum

- instruction in the relationship between product design, materials selection and manufacturing processes
- exposure of students to industrial design problems as part of the curriculum, involving them where possible in the solution in parallel with the industrial designer, and ensuring that the materials aspects of the design are properly addressed
- maximum use of instructors with industry experience, both full-time and adjunct
- linkage to scholarship programs which would reflect the foregoing priorities.

The foregoing suggests curriculum changes will require reallocation of university resources to engineering education, recognizing particularly the higher faculty/student ratio required for the effective teaching of design and the resources needed for the practical realization of the students' designs.

There is a direct relationship between teaching and research; hence, the allocation of research funds influences the teaching paradigms in the universities.

Recommendation 2
The Natural Sciences and Engineering Research Council of Canada, through its panels, should adjust its research, strategic and collaborative grants in favour of engineering faculties who focus their research on design and synthesis and who interact with industry.

For the recommended improvements in engineering education to occur, it is necessary to adequately reward faculty who take on the recommended tasks and activities.

Within the faculty, it is necessary for the dean to identify and support lead departments and individual champions who can act as change agents, and to allocate resources to support the teaching of design and materials.

Recommendation 3
Each university should adjust its reward system for engineering faculty to recognize teaching, interaction with industry and competence in design and materials on an equal footing with research achievements and specialist knowledge.

Hiring faculty with industrial experience should be encouraged, and recognition of that experience for tenure and promotion should be assured.

Interaction between Engineering Faculty and Industry

For the recommended improvements in engineering education to occur, it is essential that a closer relationship between university faculty and industry be established in four key areas: identification by industry of its expectations of engineering graduates, exposure of engineering faculty and students to industrial practice, industrial contribution to the teaching process, and collaborative research.

Given the sectoral and geographic fragmentation of Canadian industry, including the large number of firms who are not identified with any national association, many of the questions about the needs and expectations of industry can be answered only on a local basis. In some cases this has been done, or at least started. In addition to industry's need for qualified personnel, industrial practitioners need courses to upgrade their knowledge of materials technology.

Recommendation 4
Each faculty of engineering should establish a mechanism for ascertaining the needs and expectations of those industry sectors which absorb the majority of graduating students or which are most closely aligned with the technical specialties of the faculty. Where practical, this should be done on a local basis, and should include industry's need for continuing education in materials technology.

Recommendation 5
Each faculty of engineering should establish a climate in which faculty members are encouraged to interact with industry by seeking industrial experience through sabbaticals, or by consulting, or by collaborative research and development. Industry practitioners should be encouraged to join the faculty on a full-time or adjunct basis.

This climate can be enhanced by:

- directing Master's and Doctoral theses to Canadian industrial needs, including Master of Engineering theses jointly supervised by the university and an industrial firm
- strongly supporting collaborative research grants under the NSERC Research Partnerships Program, and ensuring that researchers are fully informed of this program and are encouraged to apply
- establishing (or enhancing) accessible points of contact within the university for firms wanting to access its technical expertise, potentially leading to consulting, collaborative research or other interactions
- in the hiring of faculty, giving industrial experience the same value as experience in an academic position (postdoctoral fellowship or faculty member), with design achievements being recognized at least on a par with refereed papers
- making promotion contingent on the continuing accumulation of industrial experience through sabbatical activities and interaction with industry
- establishing (or enhancing) opportunities for student exposure to industrial practice through co-op programs, internships and professional experience years, which result in increased contact between faculty and industry, with industry supporting these programs.

Teaching of Materials

The need for instruction in materials varies widely, from the computer systems student focusing on information systems to the aspiring materials specialist in the field of designer composites for hostile environments.

Better instruction in materials requires a broader recognition by the university community — both faculty and students — of the role of materials in the design of new products and industrial processes.

Recommendation 6

Within the undergraduate program, all engineering students should have (a) required general instruction on the properties and selection of materials; and (b) access to more detailed instruction on materials appropriate to their chosen discipline and electives.

An effective general materials program for undergraduates should include adequate guidance for the student on how to ascertain what instruction is appropriate and where it can be obtained. Both graduate and undergraduate programs should be multidisciplinary, typically involving several departments and more than one faculty.

Specialist materials programs should be available for those majoring in materials science or materials technology. Since not all engineering schools have specialists in all aspects of materials, it may be necessary to explore shared courses and distance education, as well as improved transferability of academic credits between universities.

Recommendation 7

Graduate programs in materials should cater to the aspiring materials practitioner as well as to the aspiring researcher. Professional Master's programs in industrial materials should be established at appropriate universities.

These programs would include both instruction in the use of materials in manufactured products and industrial processes, and a materials project to be undertaken in industry.

Recommendation 8

Initiatives should be developed to increase the understanding of the role of materials by all parties to the process of university education, including the establishment of a standing committee of long-term stakeholders.

These initiatives should include:

- a regular national design competition with a materials focus, preferably sponsored by NRC
- a national round table conference on "design with materials," focused on educational issues
- identification of champions of materials technology and research in both universities and industry, including any regional clusters of such expertise, and dissemina-

tion of this information to universities and to students who have not yet chosen their course of study.

Given that NAPAIM is both part-time and temporary, a standing committee of the long-term stakeholders should be established to ensure that materials issues and the recommendations of this working group are kept before all parties involved and are updated on a continuing basis.

This committee should be drawn from the three stakeholders with full-time staffs: the Canadian Council of Professional Engineers (CCPE), Industry Canada and NSERC. The National Committee of Deans of Engineering and Applied Sciences (NCDEAS) and the Corporate-Higher Education Forum should be asked to assist with the implementation, including the assignment of an adviser to the committee. Besides the initiatives already identified in this recommendation, this committee should encourage the advocacy by all stakeholders of the importance of materials and the evolution of networks for all activities which involve advanced industrial materials. Involvement of industry, especially industry associations, should be actively sought.

Ability in Oral and Written Communication

In every activity related to design with and of materials, it is essential that engineering graduates be able to communicate adequately, be it orally, graphically or in writing. While the roots of this problem may lie in the primary or secondary levels of the education system, the universities still have a responsibility to turn out graduates who are reasonably fitted to the employment opportunities available to them.

There is also a need to strengthen the effective promotion and use of AIM by improving the understanding by governments, the university community and the public of the essential role of engineering design and materials in restoring and maintaining Canada's prosperity.

Accreditation

The role of accreditation in improving the teaching of materials has been discussed extensively by the working group. The accreditation process should address the need for better education as expressed in Recommendations 1 and 5; however, it is recognized that unduly prescriptive requirements could inhibit the design of the most effective curriculum. The working group also expressed a desire for better industry representation, specifically by industry associations, on accreditation teams.

It is noted that, while comparisons are currently made with engineering curricula in the United States, the United Kingdom and other countries, more appropriate benchmarks for Canadian curricula might be found in other countries such as France, Germany, the Republic of Korea or Taiwan, and particularly in those countries which view their faculties of engineering as vital economic resources. It is also recognized that in many jurisdictions the approach is registration, not accreditation; nevertheless, it is the educational *outcomes* which should be compared.

Context

The foregoing findings and recommendations address the current *Canadian* scene with respect to materials, particularly advanced materials, and the impact of engineering education practices on the teaching of materials at universities and on the best use of materials by *Canadian* industry.

These findings and recommendations are largely consistent with, and supported by, a broader *international* ground swell of recognition that engineering education needs to undergo significant changes if it is to provide its graduates with the tools needed today by an engineer entering practice, and if it is to provide the industrial community, particularly SMEs, with the engineers they need to compete in today's markets.

The thrust of this ground swell is on closing the gap between the engineering *theory* taught at universities and the *practice* of engineering in industry. The principal focus is on improving the teaching of design, including its relationship with materials and manufacturing. In the past, a major obstacle has been the growing emphasis, in undergraduate education, on engineering science at the expense of engineering practice.

This ground swell includes a number of reports and actions within Canada as well as in the U.S., Europe, Australia and New Zealand. The findings of these reports support our recommendations above.

Engineering Education in Canadian Universities (Canadian Academy of Engineering).

This recent report by the Canadian Academy of Engineering specifically supports our Recommendations 1, 3, 5 and 7. The working group expressed strong support for the findings of this report.

Engineering Research in Canadian Universities (Canadian Academy of Engineering, 1991).

This report sets out 17 guiding principles for engineering research in Canada. Again, several of these principles and the general thrust of the report support our Recommendations 1, 2, 3 and 5.

Integrated Materials Technology Education: A report of the international workshop on integrated materials technology education, EDUCMAT foundation, Bologna, Italy, February 1992.

This report stresses the critical relationship between design, materials and manufacture, and broadly supports our Recommendations 1, 5, 6 and 7.

Le développement du secteur de l'ingénierie (le Conseil des Universités de Québec, 1992).

This report recommends better definition of undergraduate objectives, increased attention to design, experience requirements for professors, professional Master's programs and increased interaction with the profession. It supports our Recommendations 3, 5 and 7.

Research and Education in Mechanical Engineering (Ottawa: Industry, Science and Technology Canada, March 1992).

While focusing on mechanical engineering, this report has many recommendations which apply to other engineering disciplines and support our Recommendations 1, 3 and 5.

The Future of Engineering Education in Canada (NCDEAS and CCPE, 1992).

This recent joint report by NCDEAS and CCPE, while dealing primarily with the Canadian scene, identifies elements of this ground swell in the U.S., U.K., France, Sweden and Australia. While not addressing any specific discipline such as materials, this report clearly supports our Recommendations 1, 3 and 5 above, as well as the principle of our Recommendation 7.

Many Canadian universities are already moving with this ground swell and several have instituted programs that promise to become usable examples of successfully implementing the changes proposed in these reports. The NCDEAS/CCPE report recommends the establishment of an inventory of successful activities so that others may build on them; other reports have made similar suggestions.

Implementation

Table 1 lists the above eight recommendations and those individuals or bodies who, as change agents, should take a primary, secondary or support role in the implementation of each recommendation.

Several of these recommendations imply significant changes to the faculty reward systems for teaching, research and interaction with industry. The levers for these reward systems are variously in the hands of the engineering faculty, the university as a whole or external providers of funds for education and research. Changes to the reward system are essential motivators to bring about the recommended outcomes. Without these changes, it is unlikely that the other recommendations will be effective.

Also underlying several of the recommendations is the need for funding for certain activities within faculties of engineering, implying

Table 1. Change Agents/Stakeholders

Recommendation	Primary Action	Secondary Action	Support
1 - Teaching design 6 - Teaching materials (undergraduate) 7 - Teaching materials (graduate)	Dean of engineering Local champions within engineering faculty	Dean of engineering Heads/chairs (of engineering departments) University administration	Local industry Engineering administration Canadian Engineering Accreditation Board (CEAB) Provincial governments NSERC
2 - Redirection of NSERC grants	NSERC		
3 - Faculty rewards 5 - Industry interaction	Engineering administration Industry associations Local industry	Dean of engineering Faculty committees	University administration VPs academic, research Faculty association NSERC
4 - Needs of industry	Dean of Engineering Industry associations Local industry	Heads/Chairs Engineering administration Industry relations office	VPs academic, research
8 - Understanding role of materials	CCPE, Industry Canada, NSERC	NCDEAS, CHEF	Industry associations Provincial governments
9 - Establishing guidelines	CCPE, Industry Canada, NSERC	NCDEAS, CHEF	

reallocation of funds within a university or government funding program. This raises the general question of targeted funds, the designation of funds from governments or industry for specific purposes within the university. While this may be perceived to be in conflict with academic freedom, it is nevertheless critical that solutions be found to these funding needs. Given the collegial and departmental structure of Canadian university faculties, the recommended changes to the curriculum (Recommendations 1, 6 and 7) require the involvement of several groups, including the deans of engineering, their faculty administration and the heads/chairs and faculty of all departments, since design and materials are to be woven into the whole curriculum.

As reported in the literature, most successful changes of this type have been the result of persistent efforts over time by a few champions within the faculty. While the dean may not be the only champion, the dean's concurrence is essential if the changes are to take place.

Identification of champions, change agents and others who must be supportive can only be done on a per-university basis. However, the initial recipient of these recommendations should be the dean, who should be asked to disseminate them throughout the faculty, establish a climate where they can flourish and, if appropriate, set them in motion.

Some recommendations, particularly Recommendations 3 and 5, affect the faculty reward system involving to some degree university administrations and faculty associations. Besides the engineering faculty, these recommendations should therefore be distributed to academic (or equivalent) vice-presidents and to research vice-presidents at universities which have engineering schools.

Recommendation 4 must be tackled by both industry and the engineering faculty. While the dean must be a prime mover, industry must assume substantial responsibility for initiating such interactions. Given the special requirements of many industries, this interaction may focus on only a few departments within the engineering faculty, who should be taking their own initiatives. Industry associations (both sectoral and local) representing the principal recipients of engineering graduates should be knocking on the doors of the engineering faculty.

Part of this university/industry interface will be those involved in collaborative research with industry; most universities have an industry relations office or equivalent. Besides the industrial associations and the engineering faculty, this recommendation should therefore be disseminated to academic or equivalent vice-presidents, research vice-presidents, research administrators and industry relations officers, or equivalent, at each university.

Recommendation 5 also requires active participation by industry. Local economic development officials, who can be approached through the Economic Development Association of Canada, should be able to help with identifying appropriate firms and establishing direct links between the firms and universities.

The inability of many graduates to communicate effectively is recognized by most universities as a universal problem. This is tackled by some universities at the faculty level and by some on a university-wide basis. The working group urges that universities continue and expand these important initiatives.

The above recommendations, if taken together, represent a major cultural change for the engineering education community and the industry which it serves.

Cultural change is more easily brought about if there are visible, coherent instruments which identify the objectives and which are familiar to all involved, whether or not they agree with the changes proposed. Examples are the Ten Commandments, Magna Carta, the Declaration of Independence and Chairman Mao's little red book.

It may be useful to gather some of the recommendations of the working group into such instruments. These can take on a life of their own, independent of their authors, and can thus serve those who would crusade in the future for the desired changes. This leads to:

Recommendation 9
Sets of guidelines should be established for (a) the curriculum changes proposed in Recommendations 1, 6 and 7; and (b) the cultural, climatic and procedural changes proposed in Recommendations 3 and 5.

Preparation of these sets of guidelines should be undertaken by the standing committee suggested above for the implementation of Recommendation 8. As far as possible, these guidelines should be consistent with the appropriate portions of the NCDEAS/CCPE report, since this document will become a key reference for all change agents in faculties of engineering.

Distribution

The working group recommends that this report be distributed to all groups or bodies identified in Table 1, also to the Prosperity Secretariat, the National Research Council Canada, the Canadian Academy of Engineering, the Canadian Advanced Industrial Materials Forum, The Conference Board of Canada and officials of the provincial governments.

Follow-up

The foregoing recommendations will require several years to implement. The working group suggests that the standing committee proposed for the implementation of Recommendation 8 be charged with periodic follow-up of the implementation of these recommendations and, if necessary, with convening the necessary resources to apply corrective action.

Annex: Other Reports Bearing on the Mandate of the Working Group

Attaining Competence in Engineering Design at the Undergraduate Level, by G. R. Wray (Loughborough University of Technology, 1992).

AUCC Commission of Enquiry on Canadian University Education, Association of Universities and Colleges of Canada (RockCliffe Research, 1991).

Education of Mechanical Engineers in Design, by J. L. Duncan (University of Auckland, 1992).

Proceedings of the Eighth Canadian Conference on Engineering Education (Université Laval, May 1992).

Report on Technicians/Technologists Education

Introduction

The NAPAIM objective is to develop national strategies to accelerate the development and application of AIM and related technologies in order to maintain and strengthen the international competitiveness of Canadian industry. The specific mandate of the Working Group on Technicians/Technologists Education is to focus on the development of human resources at the college level, as one dimension of achieving greater use of AIM and related technologies.

This report identifies a number of barriers at the technicians/technologists and apprenticeship levels which impede the development and application of AIM. It puts forth 11 recommendations for overcoming these barriers.

Discussions in this report focus on two components. The first is a brief description of advanced materials and their potential, as one element of enhancing the competitiveness of Canadian manufacturing industries. The second, and indeed the more important, is the introduction of advanced materials into the curricula of community colleges and apprenticeship programs, in order to develop technicians/ technologists and tradespeople with adequate AIM knowledge.

With regard to the first component, a lot has been said and written during the past decade about advanced materials and their influence on the global economy. Advanced materials, however, remains a widely used descriptive term for which there is no commonly accepted definition. For purposes of this report, the term advanced materials refers to a specialized, high-performance, high-cost material representative of the latest in production and/or end-use technology, and used in relatively small quantities. Advanced materials are a continually changing set which through time may eventually become better known, cheaper to make, used in higher volumes, and replaced on the new materials list by even newer materials. The processes that characterize the commodity materials market are therefore a blueprint for the future of many of today's advanced materials (for further details on this issue, see the summary of a paper *Toward a New Materials Paradigm* in Annex A of this section).

For the sake of clarity, some examples of advanced materials applications are outlined in Table 2. The importance of the impact areas is reflected by the economic importance of the related industries. For example, the aerospace, automotive, biomaterials, chemicals, electronics, energy, metals and telecommunications industries had combined worldwide sales of $1.4 trillion and employed seven million workers in 1987.

Without any doubt, one of the major components for implementation of any new technological innovation is the development of human resources at all levels. As far as the mandate of the Working Group on Technicians/Technologists Education is concerned, emphasis is placed on:

- technical training in community colleges' technology programs and trade schools, designed to overcome the shortage of qualified technicians and to enhance faculty skills, laboratories, curricula and intern opportunities
- continuing education for practising technicians and tradespeople, to ensure that their skills remain competitive
- enhanced multidisciplinary curricula in materials engineering for technology programs in community colleges such as environmental technology, electronic engineering technology, civil engineering technology, chemical engineering technology, etc.

Table 2. Examples of Applications of Advanced Materials Technologies

	Application Area						
Advanced Materials Technologies	Energy	Environment	Health and Safety	Information/ Communication	Infrastructure	National Security	Transportation
Biomaterials	Catalysts, low-temperature materials processing	Biodegradable plastics, bioextraction and processing	Artificial organs and tissues	Bioelectronic sensors	Rubber, greases, lubricants	Biodegradable food containers, field medicine containers	Tires, deicers, fuels, lubricants
Ceramics	High-temperature chemical processing, fuel cells, coal conversion	Nuclear waste storage, catalytic converters, wear-resistant coatings	Bone/joint implants, artificial teeth	Electronic packaging	High-performance concrete, high temperature insulation	Heat engines, body and vehicle armour	Low-emission fuel-efficient engines
Composites	Wind turbines, lightweight structures	Waste storage and processing	Dental restoration, implants	Printed wiring	Insulating building materials	Lightweight structures for military vehicles	Lightweight aircraft and automobiles
Electronic materials	Photovoltaic conversion	Hazardous materials sensors	Heart pacemakers, hearing aids, safety alarms	Computer chips, integrated circuits	"Smart" buildings	Communications and data processing, night vision devices	"Intelligent" highway systems, advanced electronic cockpits
Magnetic materials	High-strength magnets	Waste separation	Magnetic resonance imaging	Hard disk magnetic storage, visual/audio displays	Machinery magnets	Railguns	Electric vehicles, magnetic levitation trains
Metals	Energy transmission devices	Corrosion-resistant products	Hip implants	Wiring circuits, transmission lines	Corrosion sensors	Military material	Long-life corrosion-resistant high-temperature aircraft structures
Optical/ photonic materials	Energy conversion sensors/controls	Pollution detection	Biosensors, safety control sensors, X-ray detectors	Laser systems, fibre optics, computer interconnects	Traffic sensors	Lasers, high-speed information processing	Intercity rail guides, fly-by-light aircraft systems
Polymers	Solid state batteries, gas/fluids pipelines	Hazardous waste piping, chemical separation membrane	Disposable hospital products, safety protection devices	Liquid crystal light displays	Building products, adhesives, pavements	Radar signature devices	Lightweight auto bodies, flame-resistant aircraft interiors, high-temperature adhesives and sealants
Super-conducting materials	Energy storage and transmission	Ore deposits mapping	Diagnostic imaging of human body	Supercomputers	Marine population	Electronic warfare	Magnetic levitation devices

Source: Advanced Materials & Processing: The Fiscal Year 1994 Federal Program in Materials Science and Technology. A Report by the FCCSET Committee on Industry and Technology To Supplement the President's Fiscal Year 1994 Budget (Gaithersburg, Maryland: Committee on Industry and Technology, July 1993).

Current Status

Technicians/Technologists Education

Current community college programs in Canada are working in the right direction by providing one-, two- and three-year programs in a wide variety of occupational areas. Also offered are preapprenticeship, theoretical training programs, where students are provided with a broad overview of the numerous possibilities and career opportunities in a skilled trade. Interface between the colleges and industry is also becoming more commonplace.

In Canada, approximately 200 publicly funded community colleges and cégeps (collèges d'enseignement général et professionnel) serve a large and growing student body in a wide variety of vocational courses. Enrolment in the system, however, expanded rapidly in the late 1970s and early 1980s, levelled off later in that decade and now is increasing again.

One curious aspect of the system is that, during a period of rapid technological change, enrolment in technology courses has actually declined in recent years. For Canada as a whole, enrolment in engineering and applied science as a proportion of all enrolment fell noticeably (by 25 percent) between 1983 and 1989 and in Quebec's cégep system the proportion of vocational enrolment declined by 14 percent during the 1980s.

However, given labour market realities, colleges now are seeking innovative ways to contribute to the planning, design and implementation of vocational courses in direct collaboration with local employers. There are, of course, many examples of such collaborative efforts already at play:

- Mohawk College in Hamilton, which offers numerous courses tailored to the needs of local employers, is now experimenting with "distance" education (e.g. courses delivered by television or through audio or video cassettes, etc.) to deliver vocational programs.
- The British Columbia Institute of Technology has developed a training partnership agreement with B.C. Tel which explicitly recognizes that company's in-house training and confers credits toward four of the college's certificate programs.
- In Quebec, some 15 cégeps, designated as "centres spécialisés" with the specific mandate to act closely with industry sectors, provide courses designed to import the latest skills and techniques pertinent to local industries. These range from fibre optics, laser technology and other materials-related technologies. What is especially important in these Quebec examples is the role of private firms. Local businesses transfer recent technology to the colleges by providing machinery, equipment and staff, and the colleges train technicians to work in the local industries. The bulk of the costs of the public college system is usually covered by the province; typically, less than 10 percent is raised from fees. In Quebec's industry/college partnerships, however, 50 percent of the project costs, on average, are covered by the participating enterprises (see Annex B of this section for more details).

Recent findings, however, of a survey of industrial attitudes concerning technicians/technologists education, sponsored by the Labour Market Outlook and Structural Analysis Branch of Employment and Immigration Canada, indicate the following conditions:

- Employment distinctions between technicians, technologists and engineers are blurred, especially in the manufacturing sector, and clearly distinguished functional responsibilities have not emerged in the technical work force.
- Entry-level positions are being filled interchangeably, to some degree, by technicians, technologists or engineers.
- There is some overlap between the tasks of technicians and technologists as well as

considerable duplication in terms of both the work and the technical responsibility of technologists and engineers.

- The differentiation that is often made in educational institutions between the technicians/technologists levels of training does not appear to be of significance when these individuals enter the work force. Differentiation is made only after several years of experience. If this differentiation is not made, however, the technologists are often underutilized.
- Colleges and institutes are seen to be doing an adequate job, but confusion exists in industry about the products of the educational system.
- This confusion exists due to an incomplete understanding of the educational systems that produce these technical workers, the diversity of educational programs, and the incongruence of outputs of the educational system with actual industrial practice.
- Career advancement in the technical stream can be impeded by professional, legal and educational barriers, so that promotion for technical staff is more dependent on personal ability and work attitude rather than on educational preparation.
- Technical staff are not widely nor extensively employed in the small manufacturing firms. This has a potential impact upon the national competitive position.
- At present, there are not severe shortages of technical staff nor are firms encountering recruitment problems except in specific, isolated skills areas. A decrease is anticipated in the hiring of college graduates in the near future and thus a potential increase in the unemployment rates for new graduates. However, if the Canadian economy expects to recover fully from the current recession and job losses, efforts must be undertaken to prepare the work force to seize the opportunities of the newly revitalized economy.

In order to encourage more of Canada's most promising students to pursue technology studies and careers as technicians and technologists, the Government of Canada, through Industry Canada, initiated the Canada Scholarships in Technology in 1992–93. Canada Scholarships in Technology are administered by the Association of Canadian Community Colleges (ACCC) on behalf of Industry Canada. Approximately 700 technology programs (two- and three-year programs only) within the Canadian community colleges have been identified as eligible for these scholarships, among which 20 programs are directly related to materials fields and disciplines (see Table 3).

Apprenticeship

Traditionally, European-trained immigrants have been the major source of skilled tradespeople (e.g. tool and die makers, industrial and construction electricians, mould makers and machinists). This source of skilled tradespeople has diminished significantly in recent years. With the aging work force in Canadian industry, many business persons believe that the improved education of a decreasing number of high school graduates is necessary in order to meet the human resource needs of the high-tech industry.

Despite the temporary surplus of skilled tradespeople in 1992, many business persons also believe that the educational system, as currently oriented, will be unable to fulfil industry's future requirements (i.e. "after the recession"). A key point to make is that the demands on skilled tradespeople increases over time with the advent of new technologies and manufacturing techniques.

A number of recent reports, including those of the Ontario Premier's Council, the Canadian Labour Market and Productivity Centre's Task Force on Apprenticeship, and a paper by the Siemens Electric Ltd. on this subject matter, have called for reform of the apprenticeship system. These reports suggest ways and means to integrate more efficiently the respective res-

Table 3. Materials-Related Programs in Canadian Community Colleges

Province	College	Program	Years	Hours
Alberta	NAIT	Materials Engineering Technology	2	2040
		Mineral Engineering Technology	2	2006
		Plastics Engineering Technology	2	2040
British Columbia	BCIT	Plastics	2	2100
	Camosum	Materials Fusion Technology	2	2160
Newfoundland	Western	Mineral Technology	2	2200
Ontario	Cambrian	Metallurgical Engineering Technician	2	1600
		Metallurgical Engineering Technology	3	2400
		Mining Engineering Technician	2	1600
		Mining Engineering Technology	3	2400
	Fanshawe	Manufacturing Engineering Technician	2	1440
	Mohawk	Materials Engineering Technology (Co-op)	3	2250
	Northern	Mining Technology	3	2418
	Seneca	Resource Engineering Technology (Co-op)	3	2400
Quebec	Abitibi-Temis-caminque	Mineralogy 271.03	3	2655
		Processing Minerals 271.02	3	2670
	Ahuntsic	Plastic Technology 241.12	3	2805
	Amiante	Processing Plastic Materials 271.20	3	2700
	Saint-Jérôme	Processing Composite Materials 241.11	3	2715
	Trois-Rivières	Metallurgy Technology 270.04	3	2580

ponsibilities of the private sector and the federal and provincial governments, to reform funding arrangements for apprenticeship training, to promote national standards and mobility for those who complete an apprenticeship program, and to increase the participation rates of women and other groups. The analysis of the data from the recent National Apprenticeship Survey (conducted by Statistics Canada on behalf of Employment and Immigration Canada) also casts further light on certain features of the existing apprenticeship system.

In summary, the apprenticeship system in Canada needs a major overhaul with respect to occupational and industrial coverage, coordination of standards and responsiveness to demand conditions in the labour market. Finally, employment-based training in Canada, widely judged to be inadequate by international standards, is sorely lacking in the small-firm sector — a gap that government programs have so far failed to target successfully. The following apprenticeable trades, as identified by the National Apprenticeship Survey conducted by Employment and Immigration Canada, may benefit from AIM-related programs: boilermaker, electrician, insulator (heat and frost), millwright or industrial mechanic, plumber or pipe, gas, steam and sprinkler fitter, heavy equipment or crane operator, power electrician or construction lineperson, motor vehicle mechanic, truck and heavy-duty equipment mechanic, vehicle body repairer and painter, machinist, industrial electrician, tool and die maker, industrial instrument mechanic, and marine trades.

Barriers

Although college technology programs were quite popular throughout the 1970s, enrolment has declined considerably in recent years. The reason for the decline in college enrolments in general and in technology programs in particular are complex and involve the attitudes and actions of students, parents, high schools, colleges and the labour market. Part of the problem is due to the following conditions:

- Students, parents and educators often do not view a technological education or career as a worthy pursuit. This attitude is frequently part of a more general feeling that a college education is second best and significantly less prestigious than a university education.
- Many students are not aware of what technology careers entail and view technology programs as pathways to less-than-desirable jobs.
- Guidance teachers and other high school teachers generally lack exposure to, respect for, and comprehension of technological programs and careers.
- Part of the problem lies with the exclusively masculine atmosphere which pervades some technology programs. Also, gender-related salary differentials have deterred women from attending the technology program in the colleges.

All of the attitudinal problems mentioned for the high school graduates entering technology programs also strongly exist for apprenticeship programs.

Discussion and Recommendations

Technicians/Technologists Education

The findings of the working group strongly indicate that there is a fundamental difference between those students entering a college/apprenticeship training program and those entering a university program. The former consist of students with a wide spectrum of age, different academic skills, etc., while the latter consist of a reasonably uniform group of students in every respect. Therefore, the introduction of AIM programs at the college level cannot be considered in isolation from the general problems associated with this level of training in Canada.

Overall declines in college enrolment and the prestige of a college education can be addressed only by a strategy that links college education to future jobs, within the context of the new global economy. There is also a need to re-evaluate the attractiveness of the programs once students have entered them and the types of jobs that are available at the end of their studies. Many of these problems could be partially alleviated if students entering postsecondary programs were better prepared for them and if the colleges themselves spent more time developing generic skills and providing more social support.

In preparing students for the programs and in offering them, colleges need to recognize student diversity (the combination of maturity, rich life experiences and the "rusty" academic skills often brought to college by older students, for example), to encourage student participation in the structuring of their learning, and to allow students as much as possible to move laterally among the programs without penalty.

Students must be provided with a broadened general education and sound generic skills. The accelerating pace of economic change and the need for intelligent cooperation at work demands that college graduates be able to benchmark their specific technical skills within the international and social contexts, to build on these technical skills by learning new skills quickly and enthusiastically, to communicate effectively, to work well in teams, to analyze new situations, and to solve new problems with insight and judgment.

Recommendation 1
Colleges should develop foundation courses that will provide all graduates with a common set of basic communication, numeracy and technical skills.

The need for instruction in materials will vary, for example, from the electrical and electronic technologist focusing on electrical systems to the aspiring materials technologist studying designer composites for hostile environments.

Recommendation 2
College programs in technology-related disciplines should be structured to include at least one required course in materials within the chosen technology program curriculum.

This course should be designed to give an appreciation of the materials available as well as their role in new products and processes, and should allow students to acquire a knowledge of the materials and their application.

Recommendation 3
The Association of Canadian Community Colleges in cooperation with the Canadian Council of Technicians and Technologists should establish formal consultative mechanisms with industry for purposes of updating community college curricula to include materials-related programs.

Rapidly changing economic conditions, new technologies and new research necessitate that faculty constantly learn and update their teaching materials with the latest developments in industry. The following measures can help faculty members to remain current in both their knowledge and skills: support for exchanges with business, unions and other colleges or institutions; time to conduct applied research; secondments; professional development leave; in-house training; and further education.

Recommendation 4
Colleges should provide their teachers with the opportunity to update their technological knowledge by permitting them to attend short courses offered by the universities or other external sources (e.g. consultant seminars) in the emerging subjects such as new materials.

Recommendation 5
Colleges should reward teachers who direct their efforts to teaching excellence and dynamic interactions with industry in new areas such as advanced materials.

Cooperative education and other supervised work experience components are particularly useful in promoting links between colleges and business and in ensuring industry relevance. Several colleges already offer co-op education to their students.

Recommendation 6
Colleges should expand cooperative education by including AIM-related disciplines in their programs.

While most community colleges in Canada offer technology programs, relatively few have the necessary equipment, expertise and excellence to be considered specialized sectoral or technology-specific leaders in education and training. If Canada is to excel in key sectors or technologies, a continuum of high-quality applied learning in those areas must be available in one or more colleges in major economic centres of the country. This will assist in the development of new work force entrants and the urgently needed upgrading of the existing work force. The Composite Materials Centre in Saint-Jérôme, Quebec, may be considered as one successful model of a centre of specialization in advanced industrial materials. The working group strongly believes that centres of specialization are the most positive approaches toward the introduction and diffusion of advanced industrial materials technologies.

Recommendation 7
A selected group of college technology programs should be combined into centres of specialization with an expanded mandate to become world leaders in training for certain technological specialties, including materials-related specialties.

Students in community colleges across the country should be made aware of the specialties offered in these centres. These centres of specialization should serve the following objectives:

- undertake the selection of the areas of specialty in cooperation with business, labour and community groups
- provide flexible, state-of-the-art training and upgrading of programs geared to the needs of industry and workers
- establish a level of excellence in education and training consistent with the needs of key sectors of Canada's economy.

Achieving the necessary level of specialization and excellence in these centres will require the establishment of strong linkages with industry and communities, particularly for access to and support for the most advanced equipment and up-to-date faculty. The success of these centres will also depend upon the establishment of innovative programs involving colleges, universities and focused government investment. There are currently three such centres in operation in Canada, namely, the Composite Materials Centre in Saint-Jérôme, Quebec, the specialized metallurgical products centre in Trois-Rivières, Quebec, and the newly opened Canadian Plastics Training Centre at Humber College in Toronto, Ontario.

Apprenticeship
The mandate of the working group was to examine also the appropriateness of current policies, programs and practices that affect apprenticeship training in Canada in general, and to consult on ways to effectively introduce changes to their existing curricula. There is a definite need not only to promote apprenticeship as a desirable means of providing advanced education and skills training, but also to promote it to young people who are preparing to make the transition from school to work.

Recommendation 8
Business, labour and governments, in cooperation with secondary and postsecondary learning facilities, should undertake a national campaign to promote apprenticeship in Canada as a proper and desirable form of advanced education and skills training.

It is noteworthy to mention that apprenticeship in Canada is established, regulated and administered by provincial governments. The provinces have jurisdiction for any matters pertaining to the training and certification of apprentices. In addition, the Canadian Council of Directors of Apprenticeship (CCDA) is composed of provincial representatives who not only represent their jurisdiction on the CCDA, but also have a broader role in establishing national standards through the Interprovincial Standards or Red Seal program. From time to time, industry has also acted independently to promote apprenticeship in certain trades.

One example of a concerted industry effort to address a skills shortage problem was initiated by the Canadian Tooling Manufacturers' Association in 1990. With support from Employment and Immigration Canada's Industrial Adjustment Service Program, the Canadian Tooling Manufacturers' Association organized an impressive task force including representatives from the federal government, provincial governments (Quebec, Ontario, Manitoba and Alberta) and The Society of the Plastics Industry of Canada with the overriding objective of developing a national apprenticeship program for the mould, tool and die industry. The task force took the position that education and training programs must be national in scope, driven by industry's needs and accompanied by appropriate public relations efforts to convince young people to consider the trades as a viable career choice.

The most recent effort by industry is the task force initiative by the Electrical and Electronics Manufacturers Association of Canada. The objectives of this task force, which involves Siemens, Northern Telecom, Schlumberger Industries, General Electric and a number of unions, have been to build a vigorous apprenticeship system in the electrical and electronics sector, in conjunction with community colleges and school boards in Ontario. This effort is about to be launched in the near future through a series of pilot projects.

One objective of the above discussion is to point out that, due to the internal and external forces and factors, companies are pushed to develop a training culture as a key element in their competitive strategies. Another equally important objective is to obtain the necessary insight and information to enable industry, in partnership with educational institutions and government, to design realistic and practical programs in support of companies' industrial training. The following recommendations are designed specifically to facilitate the realization of these objectives:

Recommendation 9
Governments at all levels should support industry by assisting industry associations in their efforts to promote the image of skilled trades as an attractive occupation.

Recommendation 10
The Canadian Council of Directors of Apprenticeship, in close cooperation with industry, should update and upgrade the program content of the key trades that support AIM so they reflect a new AIM technology.

Recommendation 11
The apprenticeship in technology programs should be connected with universities (engineering), and advanced degree possibilities should be offered, with credit being given for technology courses.

Implementation

With respect to Recommendation 1 on developing foundation courses, ACCC in close collaboration with community college technology departments is to review the current generic courses offered by these institutions, and make suggestions for updating and/or upgrading these courses, as required.

With respect to Recommendations 2 and 3 on introducing materials-related courses, ACCC in close collaboration with industry is to identify the required materials-related courses and encourage the community colleges to include them in their curricula.

With respect to Recommendations 4 and 5 on updating and rewarding teachers, ACCC in collaboration with the Canadian Council of Technicians and Technologists and community colleges is to establish a mechanism for sabbatical leave for technology program teachers in order that they may update their emerging technologies knowledge. Also, ACCC in collaboration with community colleges is to develop procedures to reward teachers for teaching excellence.

With respect to Recommendation 6 on cooperative education, ACCC is to encourage community colleges to consider introducing the AIM-related programs in their cooperative education.

With respect to Recommendation 7 on centres of specialization, ACCC in close collaboration with industry is to identify the appropriate community college locations in which to establish materials-related centres of specialization.

With respect to Recommendation 8 on promoting apprenticeship in Canada, the Canadian Labour Force Development Board's Apprenticeship Committee in close collaboration with CCDA is to act as the national coordinating body to ensure the further development of apprenticeship in Canada.

With respect to Recommendation 9 on improving the image of skilled trades, industry associations (such as The Society of the Plastics Industry of Canada) with assistance from the federal and provincial governments are to launch a campaign to promote the skilled trades as desirable disciplines and career choices.

With respect to Recommendation 10 on introducing AIM-related courses in apprenticeship programs, CCDA in collaboration with industry is to identify the appropriate AIM-related trades and include them in the apprenticeship programs curricula. In addition, CCDA in collaboration with industry is to review the current program content of key trades and update their programs by introducing the relevant AIM-related courses wherever applicable.

With respect to Recommendation 11 on connecting apprenticeship programs to higher education, CCDA in cooperation with ACCC and CCPE is to establish formal consultative mechanisms to investigate the possibility of extending apprenticeship program credits toward advanced degree possibilities in technology-related disciplines.

Distribution

The working group recommends that this report be distributed to all the stakeholders who were consulted regarding the report and/or participated at the technicians/technologists education round table, as well as the Prosperity Secretariat, the National Advisory Board on Science and Technology (NABST), The Conference Board of Canada and provincial government officials.

Follow-up

The recommendations outlined in this report will undoubtedly require several years to be implemented. The working group therefore suggests that a standing committee be established by the panel to periodically follow up on the implementation of the recommendations.

Annex A: Summary of *Toward a New Materials Paradigm*, by Louis Sousa (Washington, D.C.: U.S. Department of the Interior, 1992).

At one time, materials were largely synonymous with natural resources. The materials sector focused principally on extracting raw materials and processing them into a relatively limited number of homogeneous materials. These "commodities" could then be used in a wide range of manufacturing and other consuming industries. However, technology that enables new materials to be designed literally at the molecular level has contributed to an explosion in new types of materials that are being increasingly engineered to meet the user's specifications. The resulting proliferation in new types of materials has contributed to a revolution in international competition. As a result of such changes, the materials paradigm is gradually shifting from a natural resource-based and supplier-oriented model to one that is increasingly technology-based and customer-focused.

Actions of private sector materials firms have revealed a quiet acquiescence to the new materials paradigm. Since plastics are being used in an expanding array of applications once reserved for metals, former metal-only giants like Alcan, Alcoa, Armco and Reynolds have all acquired interests in plastics. The metals companies' actions have enabled them to expand their menus of materials available to customers in market ranging from construction to electrical equipment, appliances, automobiles and even aerospace.

The movement across traditional materials industry boundaries has not been one way. Large chemical firms such as DuPont and Allied Signal have staked out positions in high-tech metals and alloys such as amorphous metals, gallium arsenide and other electronic metallic materials. The "plastics firm" and "metals company" identities are giving way to the "materials company" concept.

Materials stakeholders in the academic community have also gravitated toward a new paradigm. The Massachusetts Institute of Technology's Merton Flemings described how his school's Department of Metallurgy broadened its focus in the 1950s to include ceramics, polymeric materials and electronic materials as well as metals. Since then, the department name has changed several times to reflect its evolution toward a materials department, until the present name was finally adopted: the Department of Materials Science and Engineering.

Whereas materials producers, professional societies, academics and government technologists have at least tacitly accepted a new materials paradigm, the federal materials policy community seems to have been slower to acknowledge that a new one exists. However, it now seems that interest in materials policy issues is shifting away from its traditional focus on vulnerability, national defence and the critical materials stockpile. Increasingly, materials policy issues focus on science, technology and international competitiveness topics and how they relate to economic growth. Moreover, the entire materials policy dialogue now takes place within a context of elevated environmental consciousness and expectations.

Annex B: Specialized Technical Centres in Quebec Colleges[1]

The idea of specialized technical centres was the result of a great deal of thought and discussion in college circles in Quebec, and led to the publication in 1978 of *Government Projects in the Area of the CÉGEPS*. Then, during discussions early in the 1980s about this possibility and a little later about the technological revolution, the ministère de l'Éducation du Québec of the time confirmed the government's intention to create specialized technical centres.

In 1983–84, in its economic recovery plan, the Quebec government announced the creation of such centres. Six were set up the same year, three the following year and three more in 1985–86. After a period of assessment, in 1989, the ministère de l'Enseignement supérieur et de la Science increased the number of centres to 15.

Specialized technical centres in colleges are technological transfer centres. The department has entrusted them with a mandate, as an extension of the college teaching mission, to contribute to economic development through technological transfers while helping to ensure technical training development in the colleges.

The nature of the activities in a specialized centre is directly connected with the technical training programs offered in colleges. It is in conjunction with such a program that a group of

[1] Extracted from a presentation on the *centres spécialisés* made by Rosemarie Dallaire to the NAPAIM meeting in Montreal, 4 February 1993.

professors will manifest an interest in undertaking applied research activities or in meeting the needs of business.

Cooperation among Specialized Technical Centres

These centres are found in almost all regions of Quebec and are thus able to offer their services to both regional clients and clients operating on a Quebec-wide scale. Certain centres offer their services to other parts of Canada and even abroad. In order to carry out large projects, they may pool their expertise and their personnel of some 200 engineers, technicians, professionals and administrators.

Specialized Centres Operating in the Field of Materials

Some of the centres may emphasize the development of new processes, others are involved in perfecting and developing new products, while others concentrate on innovation. Among the centres specializing in the development of new materials, the following two are noteworthy:

- the specialized composite materials centre
- the specialized metallurgical products centre.

Composite Materials

The centre specializing in the development of polymeric composite materials offers its services for the research and development (R&D) of industrial products, the development and testing of materials, the computer-assisted design and manufacture of composite materials, and the development and manufacture of prototypes in the specific field of new materials.

Metallurgy

The centre specializing in metallurgy involves the development of new alloys. The centre has designed and made an unbroken polymeric nickel-plated unit for Hydro-Québec.

Annex C: References

In the preparation of this report, the following documents were also consulted:

Advanced Materials & Processing: The Fiscal Year 1994 Federal Program in Materials Science and Technology, A Report by the FCCSET Committee on Industry and Technology To Supplement the President's Fiscal Year 1994 Budget (Gaithersburg, Maryland: Committee on Industry and Technology, July 1993).

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Report on the Diffusion of AIM Knowledge to the Manufacturing Sector

Introduction

The Working Group on the Diffusion of AIM Knowledge to the Manufacturing Sector undertook its work with the objective of developing recommendations and implementation plans that are specific to diffusion of AIM knowledge. In addition, the working group decided to target its efforts on SMEs engaged in manufacturing in Canada, in the belief that most large enterprises already have good access to AIM knowledge.

In examining the diffusion and dissemination of AIM knowledge, the working group:

- considered the business environment
- identified key stakeholders and barriers through stakeholder consultation
- examined mechanisms of diffusion and dissemination by commissioning three studies on the role of universities, industrial associations and professional associations (see summaries of these studies in Annex A), which enabled the working group to consult the private sector and academe
- developed recommendations and implementation plans.

External consultations undertaken by the working group identified the current business environment as having a very broad negative effect on technology acquisition, diffusion and use.

The working group concluded that manufacturing is a major contributor to wealth creation and jobs in Canada. Improving this sector's competitiveness was judged to be an essential ingredient of Canadian economic growth. Materials, particularly advanced materials and their processing technologies, are a broad enabling ingredient in the struggle to achieve increased competitiveness in the Canadian manufacturing sector. In essence, the adoption of new materials, associated technology and design expertise is a prime mover to achieving increased manufacturing activity and the resulting wealth creation and employment.

The working group found that the largest segment of Canadian manufacturers, particularly the SMEs, does not control the design of the products it makes and therefore is not motivated to innovation.

Innovation is a major component of increased competitiveness and wealth generation. Hence, there is a need to increase the driving force for innovation in Canadian industry. The preferred way to accomplish this is to create attractive and adequate rewards for innovation. Public funds applied to driving the innovation process are now focused on R&D activity (i.e. *part* of the innovation activity). These funds would be more effective in driving innovation if they were used to reward successful commercialization of innovative products and processes.

The working group confirmed the value of extensive networking that delivers timely and appropriate information, knowledge and expertise to SMEs. Several recommendations were developed to augment and improve the existing mechanisms.

Background

A number of developed economies, including the United States, Japan and the European Community, over the past 10 to 20 years have recognized the economic importance of materials technology. Most have incorporated various initiatives for R&D etc. in their national industrial strategies. To be competitive, Canadian industry needs to make the best use of materials, including advanced materials, in its products and processes. The National Advisory Panel on Advanced Industrial Materials (NAPAIM) was established to advise the federal Minister of

Industry on issues related to ensuring Canadian industrial competitiveness with respect to these important issues. The diffusion of AIM knowledge from various sources to companies in Canada is a critical step in a sequence of events that leads to the use of AIM by Canadians. In order to respond to its mandate, NAPAIM decided to form a separate working group to focus on diffusion and dissemination of AIM knowledge to Canadian companies.

Diffusion of AIM knowledge is a specific facet of a more general theme of diffusion of technology that has been identified as a key competitive issue in reports by three other groups: the NABST report; the Report on Challenges in Science, Technology and Related Skills; and the Fabricated Materials Sector Report (see Annex B for summaries). The working group supports generally the conclusions and recommendations of these three reports but concludes that specific recommendations and action plans developed from the perspective of materials are warranted.

The working group used the following model of diffusion of technology to the SME manufacturers in Canada:

The majority of AIM knowledge is generated outside Canada. In order for Canadian companies to use advanced materials and processes to improve their competitive position, they must:

A *have the appropriate incentives to take business risks in investing in new technology;*

B *become aware of the technology that is available (the process by which Canadian manufacturing companies become aware of new AIM technology is complex and involves many different stakeholders: Canadian companies, foreign companies, industrial and professional associations that facilitate personal contacts, universities, government laboratories, technical information centres, technical and scientific literature, etc.); and*

C *ensure that they have the financial resources and management and technical expertise to transfer and apply the new technology to their business.*

Working group activity focused on:
- identifying the barriers that prevent effective diffusion of AIM knowledge
- developing recommendations to significantly reduce these barriers
- specifying the action plans appropriate to ensuring that these recommendations are pursued.

The working group carried out its mandate with special regard to SMEs engaged in manufacturing in the belief that most large enterprises already have access to a good AIM knowledge base.

Barriers

The working group identified five major barriers to the diffusion of AIM knowledge to SME manufacturers:

Business Environment and Need: The current difficult business environment has impacted severely on business's profits and cash. The result is that there are very limited resources — both financial and human — available for reinvestment in business. This applies equally to reinvestment for physical equipment and for technology. The largest segment of the Canadian manufacturing sector does not control the design of the products it makes and therefore lacks this driving force for innovation and the related need for AIM knowledge.

Failure to Identify AIM Recipients: The number of potential recipients of AIM knowledge ranges from 5 to 20 percent of more than 30 000 manufacturing SMEs in Canada. It is difficult to identify accurately which companies are the most likely recipients of AIM knowledge and to organize any programs that would deliver information to these companies.

Limited Technical Skills: Most studies on this subject have reached a consensus that a high proportion of SMEs do not focus their managerial and financial capabilities on the benefits of the acquisition of AIM knowledge and its commercial exploitation. Technical expertise in the area of materials is often overlooked.

Weak Networks in Place for Diffusion of AIM Knowledge: Networks consist of government staff, laboratories and information centres; universities; industry and professional associations; etc. An informal materials network exists, currently based on Industry Canada's regional and Ottawa offices. This network is loosely linked with the Industrial Research Assistance Program (IRAP) of NRC. Industry associations were found to be focused largely on commercial activities, with limited involvement in dissemination of technical information. Professional associations are more focused on the dissemination of AIM knowledge, but are uneven in their effectiveness to do so. Databases were found to be insufficiently user friendly to be truly useful to SMEs.

Lack of Design Motivation at Universities: It is widely believed that universities have not developed sufficient effective links with industry, so their knowledge of AIM is not being used effectively by SMEs, and the industry has limited influence on academic research.

Discussion and Recommendations

Incentives to Take Business Risks

The single most important factor that impacts on the diffusion of technology is the motivation of the manufacturing sector to invest in new technology to achieve a competitive edge and earn attractive profits.

The highly competitive nature of the global economy is providing immense market-driven pressure to make use of the best available technology. Some of this technology can be acquired directly from others, but leading-edge companies must also use internal innovation to renew their product line while improving their cost structure.

Unfortunately, the current business environment has impacted severely on business profits and cash. The result is that there are very limited financial and human resources available for reinvestment in the business, in equipment, acquired technology or innovation. This barrier is of great importance, but it is beyond the mandate of this working group to suggest broad economic policy.

Equally unfortunately, the motivation to obtain new technology is reduced by the situation that the largest segment of Canadian manufacturing does not control the design of the products it makes and therefore lacks this driving force for innovation. The working group concluded that there is a major need to increase the driving force for innovation in Canadian manufacturing. The preferred way to accomplish this is to make the reward for innovation sufficiently attractive to encourage entrepreneurial risk taking.

The current public policy to encourage innovation is to provide attractive incentives for expenses related to scientific R&D, which is only a part of the innovation process. The result is to marginally reduce the cost burden of the complete innovation process. Additionally, the tax regulations make no distinction between successful R&D that results in manufacturing in Canada and creates wealth and jobs, and unsuccessful R&D that either fails to produce a useful product or results in investment outside Canada.

The working group concluded that the current R&D tax credit provides limited motivation to increase this important facet of Canadian wealth generation activity.

The working group concluded that these public funds applied to driving the innovation process which is now focused on R&D activity (i.e. a part of the innovation process) would be more effective in driving innovation in Canadian manufacturing if they were used to reward successful commercialization of innovative products and processes. Materials, which are broad enabling technologies, would be a major beneficiary of such a focus, and the demand for AIM knowledge would be substantially increased.

Recommendation 1
Innovation should be rewarded through a significant advantageous tax treatment for profits derived from the manufacture of Canadian designed and developed products. This action should be designed to be revenue-neutral within the tax system.

The working group noted that other advisory groups have commented extensively on related matters (see Annex B). The NABST report recommends that "the government should encourage firms to develop balanced technology development and technology acquisition strategies by establishing new tax incentives, accelerated depreciation and cost-shared funding mechanisms aimed at technology acquisition, which are as favourable as current incentives for in-house technology development."

The report by the fabricated materials sector recommends extending the scientific R&D tax credit system to include the improvement of production processes. The report also suggests that consideration be given to making R&D incentives partially contingent on commercial success. The rationale for this concept is that successful results of investments based on technical risk should be rewarded rather than the R&D activity *per se*. As noted above, the working group strongly supports this new concept.

Awareness of Available Technology
The ease of accessibility of Canadian SMEs to knowledge of AIM from various sources is a critical part of the sequence of events that leads to the use of AIM. The working group identified some key facts affecting accessibility as follows:

(a) poor identification of AIM knowledge recipients based on demand-side development
(b) weak networks in place for diffusion of AIM knowledge
(c) lack of motivation for universities and industry to network.

(a) Poor Identification
IRAP provides advice to approximately 10 000 industrial firms and contributes to R&D costs of nearly 4 000 firms per year. These firms on average would be better candidates for diffusion of AIM knowledge than a random sample of similar-sized firms because these firms are already showing an interest in innovation. These firms would become initial targets for dissemination of AIM.

The working group recognizes that the initial list would be incomplete in that a number of SMEs that could be potentially interested in AIM knowledge would not be on this list. However, the working group believes that this is a practical compromise between:

- flooding more than 30 000 Canadian SMEs with information on AIM with the knowledge that 80 to 90 percent of this information would be of little interest and would be wasted, and
- waiting until a definitive list of companies interested in AIM technologies is developed at considerable expense.

The working group believes that, with modest effort, the initial list will grow quickly to include most companies that have an interest in AIM.

Recommendation 2
Industry Canada and the National Research Council Canada should develop a compendium of all recipient firms under various Industry Canada programs as well as the Industrial Research Assistance Program, categorized by type of material used, as a starting point for a list of prospective small and medium-sized enterprises who would be candidates to use an expanded country-wide network to acquire new AIM knowledge.

(b) Weak Networks
Canada is fortunate to have an extensive and effective industry support network based on Industry Canada regional offices, provincial research organizations, universities and IRAP's industrial technology advisors network (240 strong country-wide). In addition, provincial government departments have staffs dedicated to supporting and advising industry. Through the course of a year many supportive visits are made to SMEs by technical staff.

The current materials network in reality is an informal group of Industry Canada and IRAP officials without an agreed common objective. This network meets several times a year to discuss AIM technologies. Even under these circumstances, the working group recognizes that this network has the potential to be a very valuable point for exchange of information between SMEs and other stakeholders of AIM knowledge. This network would become even more effective if industry was involved to a greater extent.

This network should be expanded to include universities and provincial government representation. While it would be impractical for all network members to meet in one place, establishing several strategically based groups based on Industry Canada, IRAP industrial technology advisors, universities, provincial government officials and private industry members would work. These regional groups could meet on a regular basis and inform other regional groups about their respective activities through newsletters, reports, etc. The primary goals of these regional groups would be to update continuously and enhance the inventory of AIM skills and expertise resident in government, industry and academe in Canada and to act as brokers between organizations looking for AIM knowledge and domestic or international organizations willing to either sell or share that knowledge. The working group recognizes the importance of industrial support for the network's brokerage activity.

Recommendation 3
The national materials network, which originally comprised representatives of Industry Canada regional offices and sector branches in Ottawa, recently expanded to include officials of the Industrial Research Assistance Program. The network should be further expanded to include provincial government and private industry representation, with the objective of assisting with identification of recipients of AIM knowledge and publicizing successful achievements based on AIM.

The study on professional associations concluded that these organizations are very keen to be involved in diffusion of AIM technology because they see this activity as an integral part of their role to enhance the professional status of their members. Thus, there already exists a willing and often able mechanism for dissemination of AIM technology.

Recommendation 4
One or more professional associations will be approached to help disseminate AIM knowledge with the help of selected firms that supply AIM and to encourage these associations

to seek closer working relations with industry associations.

The databases of the Canadian Manufacturing Advanced Technology Exchange (CANMATE) and the Canada Institute for Scientific and Technical Information (CISTI) are highly effective and very useful for the informed and knowledgeable user such as a large corporation. When it comes to SMEs, however, these databases appear to be difficult to use, according to various reports cited here. The working group suggests that some electronic surveys be carried out on the users of these databases to collect hard data to confirm this view. These surveys can be used subsequently to provide feedback for various initiatives that CANMATE and CISTI may take to make the databases more user friendly. An inventory of Canadian individuals with AIM expertise should be considered as an adjunct "people inventory" in these databases. (CANMATE was recently renamed as the Manufacturers Technology Source — MTS).

Recommendation 5
The Canadian Manufacturing Advanced Technology Exchange and the Canada Institute for Scientific and Technical Information databases that currently provide AIM knowledge to small and medium-sized enterprises should be improved by adding an inventory of people with AIM knowledge and making the databases more user accessible. A greater focus on materials information should be stressed.

(c) Lack of Motivation
The summary of a report on diffusion of knowledge of AIM from universities to small and medium-sized Canadian manufacturers mentioned in Annex A outlines a number of suggestions that would result in greater cooperation between universities and SMEs. The working group is convinced that this will work if, and only if, the onus is on universities to search out suitable contracts with the industry. NSERC grants are an effective motivational tool in this field.

Recommendation 6
A larger portion of the Natural Sciences and Engineering Research Council of Canada's Targeted Grants for University Research should be earmarked for projects involving industrially relevant problems using AIM. Similarly, industry recipients of support from various federal government programs should be encouraged to seek out practical university support for their technical problems.

Financial Management and Technical Receptor Capability of SMEs
Many SMEs have limited technical skills. All reports on the subject of technology diffusion agree that probably the second most important barrier to diffusion of AIM knowledge is the limited ability of SMEs in the area of new technology. The working group believes that the most effective way of tackling this problem is by providing the correct incentives for SMEs to invest in new technology and innovation (Recommendation 1), and by making the skills in universities, government laboratories, etc. more accessible to SMEs through better networking (Recommendations 3 to 6). Management may need to undergo a culture change in order to increase the priority given to materials.

Implementation

With respect to Recommendation 1 on supporting innovation, the NAPAIM committee is to carry forward this recommendation to the Minister of Finance for support. As a preliminary step, Industry Canada is asked to provide the resources for a NAPAIM led initiative to prepare a concrete proposal for the Finance Minister's consideration.

With respect to Recommendation 2 on recipient firms, Industry Canada is to work with NRC to develop an ongoing list of recipients of IRAP grants and to promote the firms on this list as top candidates for new material suppliers' support through an outreach technical service. New materials technical knowledge and design criteria are deemed to be those that can improve competitiveness. The firms on this list should be made aware of improved networking capabilities as they are put in place.

With respect to Recommendation 3 on networking, Industry Canada, NRC and provincial governments are to establish an expanded materials network. Private sector involvement is to be encouraged. On a regular basis, the materials network is to identify and priorize industry sectors, subsectors or regional components of sectors which would benefit most from the infusion of AIM knowledge. Emphasis would be placed on export opportunities. The materials network is to identify niche markets, domestic and export, which are particularly appropriate to the inroads of AIM. Through brokerage with IRAP, provincial governments, trade associations, etc., Industry Canada should encourage firms that have adopted new materials or processes to actively seek media coverage of their achievements.

With respect to Recommendation 4 on promotion by professional associations, Industry Canada is to facilitate a pilot program with the Ontario Association of Architects (OAA) based on inviting firms that supply new construction materials to supply commercially oriented information packages, based on their materials, for distribution by OAA. The Society of the Plastics Industry of Canada has agreed to cooperate with this initiative. Industry Canada is to extend the pilot program with OAA to other provinces and begin work with the Society for Advancement of Materials and Process Engineering (SAMPE), the Society of Plastics Engineers (SPE) and, possibly, the American Society for Metals. Industry Canada will encourage professional associations to seek closer working relations with their industry association counterparts.

With respect to Recommendation 5 on databases, gather additional information about other databases, (e.g. the United Kingdom's system, supported by the Department of Trade and Industry, and the Minnesota Project Outreach, which has been adopted by 14 other states), and compare them with Canada's CANMATE and CISTI in order to find ways of making the Canadian system more user friendly. Carry out surveys of current users of CANMATE and CISTI in order to obtain a profile of users. Develop a plan to make CISTI and CANMATE more accessible and user friendly and to increase their materials knowledge base.

With respect to Recommendation 6 on NSERC grants, the working group is to initiate discussions with NSERC to determine whether this recommendation is practical and to reach consensus. The objective will be to increase NSERC participation in AIM projects. The working group believes that increased demand will achieve positive results in this direction. This is particularly true in subsequent rounds of development of networks of centres of excellence. The working group will discuss with IRAP to determine the degree of support that can be expected for increasing university involvement. Some universities have a reputation in industry of being better universities to work with in respect of the kinds of contacts and working relationships that can be put in place. Academe is to be approached to provide more detailed information on their methods of working with industry. Results of this work will be disseminated through the professional associations, as they have a relatively high academic membership.

Distribution

The working group recommends that this report be distributed to all stakeholders.

Follow-up

The recommended follow-up to Recommendation 1 will be carried out by a specific group of panel members.

With respect to Recommendations 2 to 6, the working group believes that, once initiated, the activities resulting from the recommendations in this report will, for the most part, be self-sustaining. However, if NAPAIM is to fulfil the part of its mandate regarding diffusion of AIM knowledge, the panel should establish a new, ongoing working group to monitor progress and to encourage stakeholders to participate fully. This group from time to time would report back to Ministers on the progress, based on a set of measurement indicators that it would develop.

Round Table Discussion on Diffusion

The round table discussion on the diffusion of AIM knowledge to the manufacturing sector consisted of stakeholders from wide and diverse constituencies: two industry associations (representing some 6 000 SMEs), a professional association (representing 2 000 architects), a university professor and three federal government units with pertinent interests. As a group, the round table participants supported the working group's report. As expected with this type of exercise, there were some sensitivities uncovered in the wording of some of the recommendations contained in the draft report, most of which have been remedied in the final report. There was a universal will to participate in the activities as outlined in the report.

The mandates for NAPAIM and the working group on the diffusion of AIM knowledge to SMEs are generally confining when a discussion with such a diverse constituency is undertaken. Not unexpectedly, some discussions considered important, if not vital, to some of the participants fell outside the working group's mandate:

- the current business environment and the need to "fix" the condition before progress can be made on diffusion fronts
- the need for university researchers to be free to select the "direction" of their research, although industrial input would be deemed desirable
- the federal government's desire to have the private sector and academe assume more responsibility for the recommended actions.

Notwithstanding the above comments, there was strong agreement on the need for better networking, both domestic and international, to improve SMEs' access to timely and appropriate application of AIM. It was noted that personal contacts with individuals having the most appropriate background would always be the key ingredient to successful technology transfer. Although technology/information/knowledge networking was acknowledged to be of high priority, several participants stated that developing "market pull" for AIM continues to be the most effective starting point in the diffusion exercise. According to some participants, networks managed by the private sector could be more effective and universally more acceptable to SMEs.

In addition, it was deemed important to strongly encourage greater collaboration between industry associations and professional groups, and to have all levels of government actively seek better cooperation among all the stakeholders.

The round table on diffusion tacitly indicated that Industry Canada's leadership would be required to achieve some of the goals set out in the report. Both private sector and government participants as representatives of their organizations did not indicate any desire to provide this leadership.

Annex A: Summaries of Reports Commissioned by the Working Group on the Diffusion of AIM Knowledge to the Manufacturing Sector

Summary of a Report on Industry Associations, by The Canadian Manufacturers' Association and the Canadian Advanced Industrial Materials Forum

The central point is that there is insufficient cash and profit available to consider anything but survival strategies. Investment in technology will suffer. Therefore, the most important role for the industry associations is to lobby for improved financial and fiscal conditions.

We propose one-stop shopping for technical information, coordinated and run by industry associations because they are closest to the Business-Technology Transfer Centres.

A survey reveals the following findings:

- the most important sources of technology are a company's own R&D and shop floor activities
- the most important external sources of technology are journals, associations, networking and conferences
- the least important sources of technology are governments, government research programs, universities and technical colleges.

The study identified 800 industry associations in Canada. Of the 26 that were selected to be interviewed, fewer than 10 were multiservice organizations involved in some dissemination of technical information, and another group, also fewer than 10, were organizations dedicated solely to the transfer of technology.

No clear conclusions or recommendations were drawn, but five paradigms were proposed for considerations:

- trade technology fairs
- improved collaboration between industry associations and IRAP
- improved networking among industry associations
- an improved databank (CISTI is not deemed effective)
- a single broadly based industry association.

Summary of a Report on Professional Associations, by J. Shapiro & Associates

Four professional associations were evaluated for their ability and willingness to disseminate AIM knowledge. The four associations represent various sectors of advanced materials. The associations are:

- SAMPE — composites
- SPE — plastic materials
- the Metallurgical Society of the Canadian Institute of Mining, Metallurgy and Petroleum (MetSoc) — metals, alloys and composites
- OAA — building materials.

Of the four associations, two (SAMPE and SPE) are Canadian branches of U.S. organizations while the other two (MetSoc and OAA) are Canadian organizations. Also, one association, OAA, is a licensing professional organization, while the other three exist primarily to promote the general professional interests of the members.

All four associations were found to be interested in promoting the dissemination of knowledge relating to advanced industrial materials. The primary objective of SAMPE, SPE and MetSoc is to encourage the diffusion of technology that is relevant to the societies' members, and all three have comprehensive programs based on conferences, symposia and regular monthly meetings with that objective in mind. OAA's mission statement refers to a similar activity, but OAA's primary objective is the licensing of Ontario architects. OAA has a much less developed program of professional development and technology exchange.

Of the four associations, only SPE was judged to have a high level of ability to disseminate advanced industrial materials knowledge. SPE's program of conferences (annual and regional), symposia and local branch activities appears to be both extensive and effective. Three Canadian branches in Ontario, Quebec and Alberta have a total membership of over 1 700 and maintain a very active program of activities that provides members with many opportunities to meet with other members from industry, government and academic sectors and to exchange ideas on processing and application of new plastics. Frequent plant visits are organized, and a strong program exists to educate and encourage students to learn about the plastics industry.

For different reasons, SAMPE, MetSoc and OAA were judged to have significantly reduced ability, compared with SPE, to disseminate AIM knowledge. SAMPE's Canadian membership has declined in the past three years by 30 percent to about 210. The attendance at the Ontario chapter's monthly meetings is down to 15 to 20, and the chapter is operating at a deficit. The Canadian chapters represent only 1 percent of SAMPE's total membership, compared with 4.5 percent for SPE. The Ontario chapter needs an injection of both money and members to recover.

MetSoc gives the impression of a learned society with an active conference program but a weak or nonexistent program at the local branch level. As a result, the university, government and industry interface at a personal level may not be encouraged effectively by MetSoc. Other societies such as Canadian branches of the American Society of Metals may fill that gap. Interestingly, a new initiative by McGill University to deal with the strengthening of the university/ industry interface in the field of metallurgy is being supported by NSERC. The scope of this study did not allow a detailed review of the effectiveness of the Materials Engineering Technology Transfer Network or the American Society for Metals.

OAA has a very short history of professional development activities and technology interchange. While there appears to be a genuine need for dissemination of technology on new building materials and new building methods, OAA has not developed the programs and infrastructure to deal with this need. Apparently, no one else has either. OAA would welcome some form of help in this area.

Summary of a Report on Diffusion of Knowledge of AIM from Universities to Small and Medium-sized Canadian Manufacturers, by C. R. Cupp

Direct interviews with six universities and many contacts with academics during and prior to the writing of this report developed a myriad of mechanisms for diffusion and as many barriers.

The diffusion of AIM knowledge from universities depends to a large degree on the network(s) of the materials champion within each institution. In some cases the university will have research contracts with industry, although most are with larger firms and represent longer-term, scientific objectives. The motive for diffusion is often the desire to enter into research contracts.

The individual academic will be motivated by the need to "publish" and in most cases the subject matter will be scientific and quite pre-commercial. Academe will allocate some of its time to "technical service or problem-solving" activities. The latter are diffusion in action and will develop lasting networks for future diffusion.

The institution of an Industrial Chair, often supported by NSERC, is a diffusion mechanism but with larger companies as dominant recipients.

In Ontario, centres such as the Ontario Centre for Materials Research link multiple university centres to industrial projects. These centres have recently begun to search out industrial cooperation. This marketing activity will markedly improve diffusion.

The major barrier identified in this report was the general lack of communication channels between academe and the Canadian SMEs.

Other barriers included: the lack of incentive for academe to interface with SMEs; academe's lack of time-line urgency; almost nonexistent exchange of personnel between academe and industry; and industries', particularly SMEs', imperfect perception of the value of spending time with academe. This accentuates the fact that, in real terms, very few SMEs are linked in a meaningful manner to university networks.

The report cited the example of a network recently established in Quebec. This network is called The Materials Engineering Technology Transfer Network (METTNET) and is supported by governments and industry. It is dedicated to the assembly and dissemination of materials knowledge.

Other potential mechanisms for the linkage of SMEs to academe included: making greater use of federal laboratories; improving existing databases both in materials data content and ease of availability to SMEs; involving the provincial research organizations and provincial governments in academic networks; and involving large, materials suppliers in a teaching arrangement where students can obtain postgraduate credits in an industrial environment.

In conclusion, the report suggests that much of the knowledge resident in universities is well hidden from most manufacturing SMEs in Canada.

Annex B: Summaries of Previous Reports on the Diffusion of Technology

NABST Report

The September 1992 report of the NABST committee on *Technology Acquisition and Diffusion* submitted to the Prime Minister focuses on benchmarking as a key process resulting in the identification of competing technologies and management practices. The report recommends that government support programs should be mandated to help industry in its benchmarking in order to evaluate its performance continuously against the toughest of its competitors and the best performers in their fields of endeavour.

Furthermore, the NABST report recommends that the tax incentives now available for the development of technology by Canadian firms be extended to include the costs of the acquisition of technology. The report also emphasizes the importance of developing managerial and technical competence, consolidation and simplification of government programs and services, and the involvement of financial institutions in the introduction of technology to Canadian industry.

While the working group agrees with and supports the conclusions and recommendations of this report, it feels that a more focused evaluation of the issues specific to the diffusion of technology in the materials sector is needed.

Report on Challenges in Science, Technology and Related Skills

A 1992 Prosperity Initiative report of the Task Force on Challenges in Science, Technology and Related Skills, titled *Prosperity through Innovation*, echoes the NABST report's sentiments and recommends some of the following actions:

- improve the tax environment for commercializing innovative products, processes and services
- facilitate the rapid and effective diffusion and commercialization of best-practice technologies into Canadian firms and strengthen the receptor capacity of Canadian companies for these technologies.

The working group agrees with these sentiments and supports recommendations on both improving the tax environment for the commercialization of new technology and facilitating the diffusion of technologies into Canadian firms. However, the working group feels that recommendations and plans specific to the materials sector and to AIM are needed.

Fabricated Materials Sector Report

Similar views are repeated yet again in one of the three underlying themes that are identified in a June 1992 report submitted to the Minister of Industry, Science and Technology and the Minister for International Trade from the fabricated materials sector. The report, which was a contribution to the Prosperity Initiative, titled *Fabricated Materials: Gateway to the New Economy,* states that:

> *We are convinced that, if they are to succeed, Canadian companies must:*
> - *hire the most talented people; educate and train them*
> - *invest in leading edge technology*
> - *build a strong capital structure.*

The fabricated materials sector report sets out its recommendations in three groups, supporting the three themes. The two recommendations in support of investment in leading-edge technology are:

- improve incentives for technology investment
- locate and import current technologies.

In the case of the recommendation concerning incentives for technology investment, the report specifically makes references to the extension of the scientific R&D tax credit system to include the improvement of production processes and suggests that consideration be given to making R&D incentives partially contingent on success.

The recommendation on locating and importing current technology states that Canada must depend on technology developed outside the country in order to be competitive. SMEs do not make effective use of the federal government's programs designed to assist in accessing technology.

The working group strongly supports both recommendations of the fabricated materials sector. However, the working group believes that specific plans are now needed to put these broad recommendations into practice.

DATE DUE
