Nanotechnology & Molecular Engineering (NME)
Phase 2 Report

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Professional Engineers Ontario (PEO)
Emerging Disciplines Task Force
NME Group

NME Chair: Argyrios Margaritis, PhD., P.Eng.
NME Vice Chair: Yuri Kuzyk, P.Eng.

Group members:
Laura Deakin, PhD.
Peter DeVita P.Eng. (EDTF Chair)
Brian Haydon, P.Eng.
Roger Jones, P.Eng. (EDTF Councillor Liaison)

Observers:
Alana Lavoie
Corneliu Chisu, P.Eng.

Staff Advisor: Jordan Max

EDTF- NME Phase 2 Report

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Executive Summary

Nanotechnology and Molecular Engineering (NME) is a new discipline that is rapidly growing. NME is an enabling technology that has applications and uses in many industries. The global market for nanotechnology was valued at more than $20 billion in 2012. Total sales are expected to reach nearly $50 billion in 2017 for a five-year compounded annual growth rate of over 18%[1].

These statistics indicate the need and potential to serve the public interest through the practice of NME.

PEO, a regulatory body established by statute and accountable to the people of Ontario, recognizes that the public interest can be served and protected by licensing NME within the practice of professional engineering. As is the case with all other engineering disciplines, NME shall be regulated in the public interest by PEO in Ontario. NME presents a challenge, as this field encompasses engineering work with materials in the nanoscale, but also overlaps with other traditional fields of engineering. This reflects the horizontal nature of this emerging discipline.

The NME group issued its Phase 1 Report on March 24, 2010, which introduced and defined the discipline of Nanotechnology and Molecular Engineering. It identified the public safety risks arising from NME, applicable legislation and technical standards, and presented a draft Core Body of Knowledge (CBOK) for ethical NME practice, along with specific academic requirements and practical experience requirements for licensure as a Professional NME. The Phase 1 Report and its recommendations were approved by PEO Council on April 16, 2010 so that NME became a PEO recognized discipline of Professional Engineering.

Since that time**,** the NME landscape continues to evolve. This includes the first graduating class from the University of Waterloo's Nanoengineering program; PEO Council's adoption of NME as a new engineering discipline; the IRSST's research report on the occupational health and aspects of synthetic nanoparticles; Health Canada's release of its Policy Statement on its Working Definition for Nanomaterials, and the new Canadian standard: Nanotechnologies — Exposure control program for engineered nanomaterials in occupational settings. New nanotechnology standards from CSA and ISO are listed in Appendix C.

This Phase 2 report deals with the practice, regulatory and legislative issues required to create a fully licensed discipline in the practice of Professional Engineering.

Section 3,

[1] http://www.bccresearch.com/report/nanotechnology-market-applications-products-nan031e.html

Profile of the NME Industry and Practitioners, of this report provides the latest information on:

- public health and nanomaterials,
- a profile of NME industries,
- the role of research and industry in developing technical safety standards,
- the provincial and federal legislation nanomaterials landscape, and,
- bioprocessing regulations that might be applicable to NME practitioners.

A general observation includes an apparent gap in communicating potential health risks of nanotechnology to the public without causing unnecessary alarm.

Section 4 provides PEO Council with policy advice on the effective regulation of the professional practice of NME in the public interest for Ontario. The model could also be applied in other provinces and territories that wish to do so. This section addresses currently licensed Professional Engineers who choose to move into NME practice and required skill set thresholds that should be met.

The report recommends that PEO conduct extensive outreach and communication to universities and industry on the introduction of NME regulation to allow non-engineers sufficient time and opportunity to apply for an appropriate Limited Licence or to qualify for a P.Eng.

The report also recommends that PEO refrain from initiating any enforcement action against unlicensed NME practitioners for at least one year from the commencement of its outreach/communication activities. This permits those individuals to apply for a P.Eng. or Limited Licence.

NME Scope of Practice Definition

A scope of practice for NME is required to establish the boundaries of professional practice, and to support PEO's regulatory compliance function.

The practice of NME is a new discipline within the practice of professional engineering[2]. All requirements, obligations and responsibilities of NME practitioners derive from their obligations under the *Professional Engineers' Act*. With respect to nanotechnology and molecular engineering, this includes:

> any act of designing, composing, evaluating, planning, advising, reporting, directing or supervising, or, making measurements for, laying out work for specifying or approving of, the auditing of a general review of the classification, inventory and mapping of an activity that requires the knowledge, understanding and application of the principles fundamental to Nanotechnology and molecular manipulations; including activities related to the construction, modifications, improvements and repairs of products, processes, equipment, and systems, and including the application of nanoscience discoveries using engineering principles, where these activities or services require knowledge, training and experience equivalent to that required to become a member under this Act.

This includes those actions as may be defined from time to time under the PEO regulations wherein such applications may affect the public interest and specifically in the safeguarding of life, health, property, the environment or the public welfare.

[2] Note: NME is a child object of Professional Engineering and inherits all the properties of the parent profession.

The practice of NME is distinct from the practice of nanoscience. The latter is defined as work in pure science whose objective is the discovery of new scientific principles. Nanoengineering distinguishes itself by applying nanoscientific discoveries to innovate and commercialize equipment, products and processes.

The proposed Scope was adopted by PEO Council on September 23, 2011.

Recommendation:

That the proposed Scope of Practice, which was adopted by Council in 2011, be used by the Professional Standards Committee to develop professional practice guidelines on NME, and by the Enforcement Committee for its regulatory enforcement activities.

NME Developments Since Phase I Report

Since the approval of the Phase 1 Report, there have been some additions to the information landscape for NME.

In June 2010, the University of Waterloo's Nanotechnology Engineering Program was accredited by Engineers Canada's Canadian Engineering Accreditation Board (CEAB), the first of its kind in Canada. The 152 graduates from the first two years' graduating class are now pursuing work experience and are expected to seek licensure in NME within the coming year.

In July 2010, the Quebec-based *Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST)* released its research report *Engineered Nanoparticles: Current Knowledge about OHS Risks and Prevention Measures, Second Edition*[3]*.* The report examined the extent of knowledge about the occupational health and aspects of synthetic nanoparticles (NP), expanding on its statement "Overall, what emerges is that NP (Nanoparticles) remain an important source of concern in OHS." the report continues:

> In fact, not only does the diversity of commercially available chemical products of nanometric dimensions continue to increase, but also, the information available about the hazards specific to these substances is still very fragmentary. The literature gives us very little information specific to NP relating to their physical hazards like fires or explosions. As for health hazards, many toxicological studies on different substances have demonstrated toxic effects on various organs. It is found that in general, an NP will normally be more toxic than the same chemical substance of larger dimensions, but it is currently impossible to determine which measuring parameter for exposure is best correlated with the measured effects. The evaluation of occupational exposure must therefore address a series of different parameters, and the exposure data available are relatively rare. It should also be noted that at the present time, attention is particularly focused on carbon nanotubes (CNT), which seem to show, in different animal studies, toxicity similar to that of asbestos and consequently causing great concern in the international scientific community, mainly relating to prevention. [4]

In April 2010, PEO Council recognized NME as a new professional engineering discipline to be regulated, by passing the following motions.

That Council:

[3] Ostiguy et al., *Engineered Nanoparticles-Current Knowledge about OHS Risks and Prevention Measures, Second Edition*, Institut de recherché Robert-Sauvé en santé et en sécurité du travail (*IRSST),* Montreal, July 2010

[4] ibid

a) **recognize Nanotechnology and Molecular Engineering as a new discipline based on the evidence presented in the EDTF NME sub-group's 'Phase 1 Report on Nanotechnology and Molecular Engineering' in Appendix C-461-3.9, Appendix A;**
b) **direct the Academic Requirements Committee to develop the academic requirements (board sheets) for Nanotechnology and Molecular Engineering using the EDTF NME sub-group's 'Phase 1 Report on Nanotechnology and Molecular Engineering' in Appendix C-461-3.9, Appendix A;**
c) **direct the CEO/Registrar to develop a public awareness and messaging campaign centered on Nanotechnology and Molecular Engineering to state the policy direction that Nanotechnology and Molecular Engineering is the practice of professional engineering.**

In September 2011, PEO Council affirmed its recognition of NME as a new discipline to be regulated by passing the following motion:

That PEO Position Statements regarding Nanotechnology and Molecular Engineering (C-472-2.9.1, Appendix A) and Communications Infrastructure Engineering (C-472-2.9.1, Appendix B) be approved.

In October, 2011, Health Canada released its Policy Statement on Health Canada's Working Definition for Nanomaterials to support the assessment of nanomaterials and to provide assistance to manufacturers and other stakeholders in meeting their respective statutory obligations for the health and safety of Canadians, pursuant to applicable Acts and Regulations[5].

Standards related to nanotechnologies have been under development since 2005 at both the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC). Canada has an active, nation-wide committee facilitated by CSA (Canadian Standards Association) Group that provides input to and experts for the development of science-based international standards in the field of nanotechnologies.

As of October 2013 35 new nanotechnology standards from ISO/TC229 and IEC/TC113 have been published with more than 20 other standards underway, developed by TC working groups on *Terminology and Nomenclature*; *Measurement and Characterization*; *Health, Safety, and Environment*; *Material Specifications*; and *Performance Assessment*. The new standards are listed in Appendix C.

In October 2013 University of Toronto hosted the iGEM (international Genetically Engineered Machine) regional jamboree for North America. University teams from across North America displayed examples of synthetic biology applications based around iGEM's open source" registry of standard biological parts".[6] The registry has grown from its origins at MIT to now have more than 7000 DNA samples. High schools are now involved in similar competitions. The rapid advancement of synthetic biology is enabled through developments in nanotechnology with liaison between these disciplines strongly recommended.

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[5] Health Canada Interim Policy Statement, more information at http://www.hc-sc.gc.ca/sr-sr/consult/_2010/nanomater/draft-ebauche-eng.php
[6] iGEM website with further details on their registry: http://igem.org/About

Summary Of NME Phase 2 Report Recommendations

Rights to Practice Recommendations

Enforcement Committee Recommendations

1. *That Council direct the Enforcement Committee to use the proposed Scope of Practice for its regulatory enforcement activities.*

2. *That Council direct the PEO Enforcement Committee to create an enforcement plan, to be initiated one year from date of Council's NME motion, to allow for individuals to qualify for a P.Eng. or Limited Licence in NME.*

3. *that PEO Council direct the Enforcement Committee to investigate within six months ways and means so that PEO can use the courts to establish 'Common Law' rulings that support these recommendations; and,*

Professional Standards Committee Recommendations

1. *That Council direct the Professional Standards Committee to draft a professional practice guideline for NME within six months for reference by P.Eng.s wanting to enter into NME practice. EDTF recommends that the following elements contained in this report be included in the guideline:*
   a. *a definition of the Scope of Practice and potential activities in addressing the scope (Executive Summary of this report);*
   b. *identification of the potential risks to human health from non-professional practice (section 2 of this report);*
   c. *reference to the NME Core Body of Knowledge (as detailed in the April 2010 Phase 1 report);*
   d. *identification of the applicable international and industry standards, federal and provincial legislative and regulation requirements applying to NME (section 3 and Appendix C of the Phase 2 report); and*
   e. *identification of Professional Practice throughout a nanoproduct's lifecycle, including laboratory design, development, and testing, commercial fabrication, handling/ shipping, and safe disposal of end-of-cycle nanomaterials.*

Legislation Committee Recommendations

1. *That Council direct the Legislation Committee within six months to consider amending section 46 of Regulation 941 to provide a mechanism for non-engineering work experience that would be relevant to an application for a limited licence similar to that being examined for Natural Scientists.*

2. *That PEO Council expand the Terms of Reference of the Legislation Committee to enable them to handle the following recommendations, (in the alternative, Council will need to determine who within PEO will provide Council with advice on how to proceed with actions requiring new Demand Side Legislation.)*

3. *that PEO Council direct the Legislation Committee to research the legislation within six months to determine what can be done to add demand legislation requirements to support the licensure and rights to practice in NME Target Domains listed above, and in any others that may from time to time come to be known, and that PEO Council consider, as policy, those recommendations from the Legislation Committee that are relevant to support these recommendations.*

4. *That Council direct the Legislation Committee to identify within six months government ministries at Federal and Provincial levels that can create mandatory reporting of incidents to the Provincial Engineering Licensing Authority, PEO, where Public Safety is at risk due to works related to the practice of Nanotechnology & Molecular Engineering; and, that PEO Council direct the Legislation Committee to pursue courses of action that create mandatory reporting requirements;*

Registrar Recommendations

1. *The EDTF-NME group recommends that PEO communicate with universities and industry on the introduction of NME regulation to allow non-engineers the opportunity to apply for an appropriate Limited Licence or to qualify for a P.Eng. Licence. Action: staff to proceed per Council direction.*
2. *The EDTF-NME group recommends that NME practitioners be regularly informed of new regulations, codes and other legislations for nanomaterials, and, that such developments be posted on PEO's web site for general public access.*
3. *That PEO Council direct the Registrar to create an administrative plan within 3 months of approval of this recommendation that is to be approved by Council, that will permit Councillors to access and track approved initiatives of Council along with their current implementation status.*

Admissions/Academic Recommendations – Enhancements to Phase 1 Report

1. *That Council directs the Academic Requirements Committee within six months to create a board sheet for NME, using the CEQB Nanotechnology Engineering Syllabus found in Appendix B of the Phase 1 report. [enhanced phase 1]*
2. *That Council directs the Experience Requirements Committee within six months to review and adopt the proposed experience requirements for NME as contained in Appendix H of this report as they pertain to the five criteria.[enhanced phase 1]*

Other/Special Recommendations

1. *Standing Committee Recommendation*
   The EDTF supports and recommends to PEO Council that it create a standing committee to horizon watch for 'New Engineering Disciplines and Practices'.

2. *Certification Process*
   The EDTF recommends that PEO Council establish a new process to handle an enhanced certification. This is equivalent to the processes used by medicine and law to recognise specialist practices and grants those who are qualified the right to a title/designation that they may use to market their services.

3. *Engineering Licence Credentials*
   Whereas the EDTF recognizes that the full Core Body of Knowledge of these new disciplines is likely to exceed the time available to teach these subjects in the typical undergraduate curriculum, we recommend that Council direct the Licensing Process Task Force to urgently examine this matter and to recommend an appropriate course of action to Council within six months.

4. Policy Recommendations – Target Domains

   a) *Whereas the fields of engineering practices tend to be broad in their world application and ever widening as new technologies are created, EDTF recommends that, PEO introduce the concept of Target Domains within its rubric*[7] *to assist in the regulation and governance of engineering practice.*

   b) [8]*In order that the public interest be served and protected by engineering practice the EDTF-NME group recommends the following initial Target Domains:*
      i. *That the design of medical equipment and the processes to make such products that use Nanotechnology is a domain for the practice of NME ;*
      ii. *The design and manufacturing of NME-based pharmaceuticals is a Target Domain of NME.*

[7]an established rule, tradition, or custom

[8] This concept allows the sub-partitioning of practices by referencing the target world objects of applying a specific engineering skill set, e.g. for CIE: Medical field, SCADA Smart Grid, Finance Sector, etc. It is important for PEO to assess which TD's have the greatest impact on the public interest and to use this assessment in prioritizing regulatory activities in Enforcement, Legislation, and Guidelines to match such priority. See Appendix E - Target Domains for more information.

1 Introduction to Main Report

1.1 EDTF Current Mandate and Terms of Reference

In November 2008, PEO Council directed that an Emerging Disciplines Task Force be created to deal with the two subject of engineering within internet related communications and with the fields related to Nanotechnology.

The mandate was set out as:

"To investigate and advise Council with respect to emerging areas of professional engineering practice, in particular with respect to:
1. Nanotechnology/molecular engineering ***[NME]*** *and,*
2. Communication infrastructure engineering ***[CIE]"***

The Terms of Reference are:

[Phase 1] - **COMPLETED April 2010 for NME, September 2010 for CIE**

1. *"Identify issues relevant to PEO in these areas relating to established or anticipated practices;*
2. *Make recommendations to Council on action required, in particular defining the core body of knowledge of these disciplines;"*

[Phase 2] **- PENDING APPROVAL**
1. *"Make recommendations to Council regarding Licensing of these areas of practice, including establishing rights to practice and enforcement concepts;*
2. *Provide advice and support on professional practice and admissions in this area;*
3. *Support external relations where appropriate;*
4. *Evaluate existing certification programs relating to these disciplines as they may impact the responsibility of PEO to license the practice of engineering."*

PEO, a regulatory body established by statute and accountable to the people of Ontario, recognizes that the public interest is both served and protected by licensing NME as the practice of professional engineering. As is the case with all other engineering disciplines, NME shall be regulated in the public interest by PEO in Ontario as set out in the Principal Object in the *Professional Engineers Act,* whichstates:

"Principal object
The principal object of the Association is to regulate the practice of professional engineering and to govern its members, holders of certificates of authorization, holders of temporary licences, holders of provisional licences and holders of limited licences in accordance with this Act, the regulations and the by-laws in order that the public interest may be served and protected."

1.2 Canadian Law Perspectives

It is a well established tenet in Canadian law that licensure can only be justified when the public interest (meaning the welfare or the wellbeing of the general public) is enhanced by so doing. Otherwise, a license would be a restriction on democratic freedoms.

In defining a Licence, in 1983, on the occasion of the First Reading of Bill 123, The Professional Engineers Act, the Ontario Attorney General Roy McMurtry said in the House:

"A license is an exclusive right to practice an occupation."

Minister McMurtry went on to say:

> "As a general principle, every person should be free to utilize his or her abilities, education, training, and experience in earning a livelihood. Therefore, it is wrong to create a restriction on this general principle by establishing Licences, unless this legislature is satisfied that licensing is necessary to protect the public."

McMurtry is relying on previous works in law to support what he said. One of these is by Justice McRuer who wrote in the 1968 Report of the Royal Commission of Inquiry:

> *"What has to be safeguarded against is the use of the power to license for purposes other than establishing and preserving standards of character, competence and skill."*

Hence, the purpose of a self-regulating body like PEO is very clear. It is crucial that we fully understand the public interest impact in any discussion of Licensing.

Licensure is a privilege conferred by government and not an absolute right. To maintain the confidence and trust of their public, professions must act in ways to ensure that the actions of their licensed professionals will always be for the good of the 'public interest'. Without this trust, the foundations of self-regulation break down.

PEO's authority derives from this fundamental as does the authority of all other self-regulating professions in Canada. PEO's mandate to regulate this new practice, or any engineering practice, flows from this authority.

Licensed individuals have the required skill set as well as meet the good character requirements. Clearly, if one is NOT licensed one is NOT permitted to do such work. That is the ONLY way a licence actually works, that is, in stopping the unqualified. The government of this province empowers the self-regulating licensing bodies with the authority to grant such licenses, that is, with the authority to say who can and who cannot practice in a licensed profession

Our report shows that the public interest is enhanced (served and protected) by introducing the licensing of NME skilled individuals.

1.3 Enforcement is the essence of licensure

If one cannot or will not stop unlicensed individuals from practicing, the licence loses its meaning. It simply becomes a right to title.

This EDTF is aware that previous Task Forces dealing with Software Engineering and Bio-Engineering have not seen anticipated success in establishing rights to practice in spite of Council accepting all recommendations. Here, in Phase Two, we seek to push the envelope as much as possible by identifying those works that constitute part of this new practice, and, to make recommendations for PEO's key regulating committees to achieve a proper licence. Our objective is to reach into the implementation mechanisms as much as possible to provide guidance on what is specific to NME to effect rights to practice.

The practice of engineering is not static – the reason we have EDTF in the first place. Hence, we cannot provide static solutions. Instead, EDTF has focused on the processes required to effect proper licensure on an on-going basis.

1.4 Some EDTF Background

In previous work, notably the EDTFs on Software Engineering, we grappled with the issues on how to establish rights to practice that gives the PEO Licence true meaning. PEO established a joint committee with CIPS (Computer Information Processing Society), the most significant society representing the interests of computer science related practitioners. The work established some important principles by dividing the broad field into practice segments or “domains of practice” with varying risks to the public interest. Not all domains require a licensed practitioner.

These early discussions of domains within which practitioners require specific domain expertise, has lead to the concept of **“**Target Domains**”** introduced in this report. These assist in partitioning the task of regulating and governing a specific practice within the profession.

Our past experience with Software Engineering and Bio-Engineering shows that we were reasonably good at the Phase 1 reports. Our Phase 2 experience has not been so positive. Even with the right recommendations approved by Council nothing much happened to actually create a 'closed' practice. Engineers' Canada is attempting to address this now with Software Engineering.

It seems to take decades for these ideas to permeate the consciousness of the profession. That is far too long a response time. The public is exposed while the profession works out what it needs to do. The profession must improve its ability to respond to new practices in engineering.

1.5 Phase One and Phase Two Reports

Based on EDTF’s Phase 1 report in 2010, PEO Council designated NME as a new practice within professional engineering. The report dealt with the Core Body of Knowledge (CBOK) required to educate new practitioners to this field. This Phase 2 and final report, deals with the practice, regulatory and legislative issues that are required to create a fully licensed discipline within the practice of Professional Engineering.

Engineers like to focus on Core Body of Knowledge (CBOK) matters, ones they understand and have great comfort in discussing. The risks to the public, however, are about rights to practice and the really challenging legal matters of phase two. If we do not address these properly PEO will only be issuing a ‘quasi’ licence. We could just as well be a certifying body with only a right to title and no power to protect the public welfare. That would put the people in our society in great danger from unqualified practitioners.

Phase 2 of our EDTF work is the most difficult. Our experience with Software Engineering and Bio-Engineering has established the methodology for Phase 1 work, that is, in defining the CBOK for the new discipline, meaning, we have identified a new skill set in the growing practices of Professional Engineering. The CBOK is useful to Engineering schools to establish new programmes of study, and, to PEO's admission processes to help identify individuals who apply to PEO.

Phase 2 work deals with applying this new skill set and focus on the concept of the Licence to Practice. We answer the question, "where is this new skill set applied to real world engineering practice?". The public interest question is being raised within this report because the act of doing engineering impacts the public. These considerations give rise to the issues surrounding exclusive rights to practice.

In our meetings with regulatory committee chairs, it was clear that the admissions work (Academic Requirements, Experience Requirements, and Registration Committees) was the most straightforward. This is not a surprise since the Phase 1 report dealt mostly with issues relevant to this activity in PEO.

Our thrust in Phase 2 is therefore focused on the Enforcement Committee, the Legislation Committee and the Professional Standards Committee.

We also hope and expect that PEO's Government Liaison Program (GLP) along with coordinated help from the Ontario Society of Professional Engineers (OSPE) will provide the external reach to our politicians and governments to make the changes necessary for proper licensing of this new practice in Engineering.

1.6 NME

Nanotechnology and Molecular Engineering (NME) is a new discipline that is rapidly growing. NME is an enabling technology that has applications and uses in many industries. The global market size is already into the $100's of billions and potentially reaching into the trillions within this decade. The statistics indicate need and potential to serve the public interest through the practice of NME.

In contrast to the potential to serve, there is also a potential for public harm in both the processes used and the products created in the practice of NME. During the manufacturing or research works (processes), there has been evidence of potential risks to public safety based on for example, inhalation studies of specific nanoparticles. There is also potential risk for accidents that could affect the public. There is uncertainty as to the toxicity of many nanomaterials with possibly complex interactions of nanoparticles and the environment. At present, there is minimal legislation specifically governing these materials, limited education on risk management for those who are practicing this new discipline, and limited safe practice guidelines for handling nanomaterials.

NME enables the creation of new life forms with unpredictable properties or performance. The precautionary principal must be used to ensure that new life forms or new nano level particles are safe for humans and the environment.

By licensing NME, we can rely on the Engineer's code of ethics and good character to ensure that innovations are for the good of humanity.

2 The "Public Interest" of NME

Hazard Analysis

The engineered products of nanotechnology apply an interesting mix of materials. Some are well-known and well-studied in their bulk phases, such as titanium dioxide and silver, but many can now be produced in reduced dimensions at the nanoscale. Other materials, such as carbon nanotubes, are entirely new. These tube-like structures can be many microns in length forming fibers or bundles, but are only a few nanometers in diameter. Some engineered nanomaterials exhibit new properties that have led to, and will continue to lead to, new products including nanomedicines, and modified materials for enhanced strength, as well as instruments, catalysts, antibacterial coatings, and as additives in consumer products such as cosmetics or paints. A growing list of these products is available to the public, for example, through the Project on Emerging Nanotechnology (PEN) Woodrow Wilson Institute (http://www.nanotechproject.org)

The public health hazards resulting from exposure to these engineered nanomaterials will be as varied as the materials themselves. Therefore, it becomes important to recognize that a generalization of the hazards of these nanomaterials cannot be made. When separated into occupational, consumer and environmental hazards, there are certain substances or material properties that are believed to have the potential of presenting hazards to either workers or the general public. These different aspects of public health risks are presented below.

Occupational impacts

The workers implicated in the production, modification, use, and transport of engineered nanomaterials will be the ones handling pure material and therefore these are the people at risk of the highest exposure. In this sense, the occupational health risks are similar to those handling chemicals, however the material safety data sheets designed to help warn workers of hazards are not yet well developed or as informative for the new and highly variable products of nanotechnology.

The protection of workers is accomplished by setting occupational exposure limits (OELs) and sampling workplaces to ensure industry is in compliance with this limits. To date, there are no Ontario OELs for nanotechnology substances. When faced with limited information or uncertainty in the toxicity of materials, workers manipulating engineered nanomaterials will need to evaluate what processes they feel have the potential of generating high exposure scenarios where risk may exist. Decreasing these potential exposure situations will be important method of mitigating risks of adverse effects associated to exposure of these engineered nanomaterials. Exposure control to nanomaterials in an occupational setting is the subject of the Canadian standard CSA Z12885-12 (see Appendix C). The risks of occupational disease related to nanomaterial inhalation can be mitigated, for example, by installing alternative ventilation with HEPA filters for nanomaterial capture, by avoiding work with dry powders, or by having workers wear particle respirator masks.[9] As of yet, there are no results indicating that nanomaterials are capable of being absorbed into the body via contact with skin, but gloves will need to be evaluated to determine if they are an effective barrier to nanoparticles. Workers will also have to keep in mind that their personal protective equipment may not have been tested with the nanomaterials they are manipulating.

[9] NIOSH. National Institute for Occupational Safety and Health. Approaches to Safe Nanotechnology. 2009. Available online: http://www.cdc.gov/niosh/docs/2009-125/pdfs/2009-125.pdf

The materials presenting the greatest hazard to this group of people are those capable of being in released as aerosols when produced, manipulated, or transformed. While there is very little information on engineered nanomaterial effects on humans, there is a continued interest in this field with many publications examining the toxicity of these materials on animals. Toxicological studies have provided insight into the effects of inhaled nanomaterials, though the relationship between toxicity and particle composition, size, shape, or concentration and effects is not consistent. Some studies have observed increased rates of inflammation in the airways upon decreasing particle size, while other studies report the travel of these small particles from the airways into other organs. The hazards of engineered nanomaterials are complicated by the tendency of nanoparticles to aggregate, along with the inherent variability in composition, structure, or surface. This is the case for carbon nanotubes that can be produced and treated to yield a material with highly variable physical and chemical properties. In one study, this engineered fibrous form of carbon has resulted in malignant mesothelioma in animals, and it is being studied to determine if it has the potential of demonstrating similar properties as asbestos, which is linked to malignant pleural mesothelioma in humans[10].

Consumer impacts

The hazards presented to the public differ from those presented to the workforce taking part in the manufacture, testing, modifying and handling of devices containing engineered nanomaterials. The consumer will be the next in line along the lifecycle of the product. Now the hazards are generally not thought to be a result of particle inhalation but due to dermal contact. Generally, the consumer health risks could be considered to be lower than occupational risks as the nanomaterials are generally either embedded into a matrix or adhered onto the surface of a solid. Canadians are further protected with the new Canada Consumer Product Safety Act.[11]

The health risks to consumers due to nanotechnology products in cosmetics is being discussed in the scientific literature, as these products are designed to be applied onto the skin. There are already several skin care products available that contain nanomaterials, for example nanotitanium dioxide or nanozinc oxide particles for sun protection, or fullerene (also called C_{60}) as an anti-oxidant or in creams for acne treatment.[12] Particle reactivity on the surface of skin, and particle penetration into deeper layers of the skin continue to receive much attention in the scientific literature. The consumer's trust in nanomaterials is complicated by the consumer's inability to clearly understand labels and the true nature of the material that has been incorporated into their products.

The Consumers Council of Canada released a report[13] that investigated the impact of nanotechnology on consumers due to its wide spread use in consumer products and its potential beneficial and adverse impacts on human health, safety and the environment. The purpose of the investigation and the report was to improve the capacity of consumers and consumer organizations to inform and effectively represent consumers in decisions being made by governments, industry and standards organizations. It was intended to provide them with

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[10] Jaurand, M-C. F.; Renier, A.; Duabriac, J. Mesothelioma: Do asbestos and carbon nanotubes pose the same health risks? Particle and Fibre Toxicology 2009.,6:16

[11] This Act was passed by Parliament on October 29, 2010 and came into force on June 20, 2011. It replaced Part I of the *Hazardous Products Act*, creating a new system to regulate consumer products that pose, or might reasonably be expected to pose, a danger to human health and safety.

[12] PEN. Project on Emerging Nanotechnologies. Woodrow Wilson International Center for Scholars. Inventory of Consumer Products. 2011. Available online: http://www.nanotechproject.org/

[13] Consumer Council of Canada, Nielsen, E., Nanotechnology and Its Impact on Consumers, 2008. http://www.consumerscouncil.com/site/consumers_council_of_canada/assets/pdf/Nanotech_report.pdf

objective background information on nanotechnology. The report raised similar concerns mentioned in the EDTF NME groups Phase 1 report. It concluded:

> As consumers become more aware of the nano enhanced products being sold, it is expected that they will demand that government identify, consider and weigh any associated risks and benefits in some meaningful way before the products are marketed. Taking advantage of technological progress and preventing adverse side effects requires careful consideration and guidance to ensure the technology is developed in ways that benefit society and the environment.

Although the report found that 70% of the consumers surveyed did not know about nanomaterials, 58% of consumers have no concerns. The report made another interesting observation about the role of communication with regards to educating consumers about NME.

To maintain this positive attitude much will depend on the information they receive in the future about the associated risks and benefits and their experience with nanoenhanced products. This suggests that a concerted effort needs to be made by the federal and provincial governments to inform and to engage consumers on the subject. Also, since most Canadians reported that they obtain information about nanotechnology from the media, the attitude of Canadians will also depend on the direction that the media takes in presenting the technology. Efforts to work with and provide balanced information to the media will be crucial in ensuring that the information received by consumers is accurate and balanced.

Environmental impacts

The environmental aspects of the hazards of engineered nanomaterials may suffer from even greater complications. These materials could make their way into the environment as a result disposal of products, via unintentional release during manufacture or from intentional release. Matrix embedded nanomaterials, such as nanoparticles incorporated into resins or paints are not likely to release the original nanoparticles, even after material degradation occurs post-consumer use. The washing of textiles coated with nanosilver or the disposal of silver-coated products may result in an increase in the amount of silver transferred to the environment. There is widespread use of nanosilver as an anti-microbial agent, now found in disinfectant cleansers, textiles, toothbrushes, household appliances, kitchenware, phones, and infant toys and furniture.[14] There are also reports in the scientific literature of engineered nanomaterials designed to be deliberately released into the environment for soil remediation. Nanoiron is currently being tested in this fashion, as it is injected into soils contaminated with chlorinated organic compounds.[15]

A look into the future

The future impact of engineered nanomaterials will likely span across many fields that could impact Ontarians and the Ontario economy, with current studies or product developments already leading to important contributions in a wide-variety of areas. The importance of nanotechnology in medicine can already be observed from the many patents and peer-reviewed publications on drug delivery, medical sensors and medical imaging. Nanoagrochemicals and pesticides will bring nanotechnology to Ontario farmers, and nanoscale formulations within vitamins, foods and food packaging will bring engineered nanomaterials into Ontario homes. In the area of enhanced materials, concrete, glass, composite materials, coatings and paints containing products of nanotechnology are being tested. Nanotechnology is expected to have a

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[14] PEN, 2011.

[15] EPA, 2008. Nanotechnology for Site Remediation Fact Sheet http://www.epa.gov/tio/download/remed/542-f-08-009.pdf

large role in a variety of Advanced Electro-Chemical Devices, many of these being in the alternative energy and power grid storage arena. Work to improve solar cells, fuel cells, secondary (storage) cells and catalysts is already in progress and will increasingly use nanomaterials and related technologies. Nanoinstrumentation, including x-ray optical systems, chemical sensors, nanobiotechnology, as well as robotics and molecular machines are either currently being developed or are not too far off on the nanotechnology horizon. Public safety issues of concern to Ontarians are expected to arise, also affect the well-being of Ontarians and the Ontario economy. Thus, product design, engineering and application will be an engineering practice under the *Professional Engineers Act* and, as such, will need to be regulated by PEO.

Nanomachines will be constructed at some point, having as yet unknown characteristics and applications. This nanotechnology may well incorporate biological components. NME will be a core discipline, using expertise from the Electrical, Mechanical, Software and Bio-engineering. Thus, nanomachines will be regulated by PEO under its public safety mandate.

3 Profile of the NME Industry and Practitioners

Today, nanotechnology is still in a formative phase—not unlike the condition of computer science in the 1960s or biotechnology in the 1980s. Yet it is maturing rapidly. Between 1997 and 2005, investment in nanotech research and development by governments around the world soared from $432 million to about $4.1 billion, and corresponding industry investment exceeded that of governments by 2005. By 2015, products incorporating nanotech will contribute approximately $1 trillion to the global economy. About two million workers will be employed in nanotech industries, and three times that many will have supporting jobs.[16]

No specific funding program has been dedicated to nanotechnology in Canada, although a significant amount of infrastructure has been developed in recent years including the $52.2 million dollar, 20,000 square meter research facility at the National Institute for Nanotechnology, the federal government's flagship nanotechnology research institute[17].

Biotalent Canada, which is the federal government's sector council, defines the bio-economy as involving: "… the research, development, manufacturing and commercialization of technologies and products for such areas as:

- Agriculture
- Aquaculture
- Bioenergy
- Bioinformatics
- Bioproducts
- Biosciences
- Environment
- Food Processing
- Forestry Genomics
- Human and Animal Health
- Industrial
- Life Sciences
- Medical Devices
- Natural Resources
- Nanotechnology
- Nutraceuticals, and
- Pharmaceuticals"[18]

Engineering plays a crucial role in the development, manufacturing and commercialization of technologies, new products and processes. Clearly there is an overlap with the subject matter covered by Biotalent Canada.

The most recent information provided by Industry Canada[19], indicates 61 companies involved in nanotechnology with head offices based in Ontario alone. Presently there are more than 130

[16] F Yegul, M Yavuz, P Guild. PICMET 2008 Conference Proceedings, Technology Management for A Sustainable Economy. Cape Town, 2008.
[17] http://archive.nrc-cnrc.gc.ca/eng/facilities/nint/general.html

[18] Biotalent Canada website: http:// www.biotalent.ca
[19] Industry Canada. Company Directories. Available at: http://www.ic.gc.ca/eic/site/aimb-dgami.nsf/eng/03503.html

companies in Canada.[20] A list of those companies and where identified, the number of employees, is provided in Appendix B.

Industry Self-regulation for Commercialization of Nanotechnologies

The nanotechnology industry can only be relied upon to voluntarily assume the level of safety that is most economically beneficial for itself; however, this is not necessarily the optimal level of safety for society as a whole. The loss of consumer confidence could effectively cripple the industry as a whole—without consumer confidence the potential market for nanoproducts would dry up, and without a potential market, nanotechnology research funding would likely decline. The main benefits to businesses that are involved with nanotechnology to self-regulate are:

- Minimization of emerging business risks
- Additional stimulus to innovation
- Added social legitimacy

However, the present business attitudes may be summarized by the following[21]:

- a belief that responsibility is "part of the territory"
    - systematic/formalized corporate social responsibility (CSR) is not a central part of business
    - imposes unnecessary costs
    - has little positive effect

Commercial scale process plant

In addition to laboratories, experimental processes, pilot plants and product regulations (commercial scale process plant and equipment, and manufacturing plant and equipment) must be designed to be safe against all foreseeable events. (see Appendix F for further detail). These items address an expected future, where nanomaterials will play an increasing role in various manufacturing and/or extraction processes, either as key ingredients in the final product or reactive components to aid extraction, concentration and production. We expect to import various practices from the commercial pharmaceutical industry in the absence of specific NME directives.

NME Labour Market considerations

As there have been no P.Eng's licensed in the NME discipline to date, PEO's database does not indicate which current P.Eng's are working in this field. This information will only become useful once the recent University of Waterloo graduates or foreign-trained nanotechnology engineering graduates apply for licensure in Ontario (by 2014 at the earliest).

A 2011 report from the Information and Communications Technology Council (ICTC) on the Nanotechnology Labour Market indicates that many Canadian nanotechnology jobs are found in the research and development fields, particularly in large companies, universities, and various federal agencies or government initiatives, but relatively few exist in the private sector at this

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[20] ICTC, Nanotechnology Subsector Study: Canada's Evolving Nanotechnology Industry and Future Implications for the ICT Labour Force, 2011. http://www.ictc-ctic.ca/uploadedFiles/Labour_Market_Intelligence/Enabling_Technologies/Nanotechnology/Report_Items/Nanotechnology%20Executive%20Summary.pdf

[21] Centre for Business Relationships, Accountability,Sustainability and Society, "Corporate Social Responsibility and the UK Nanotech Industry", http://www.matterforall.org/pdf/3-Chris%20Groves.pdf

time. These jobs are typically at the graduate, Masters, PhD or post-doctoral level, with titles such as research assistant or associate or fellows or researchers, and cover a wide range of topics from the study of nanophysics to nanofabrication.[22]

In the private sector, most nanotechnology jobs require engineering or science degrees and focus on areas such as medicine, semiconductors, manufacturing, and chemicals. Mechanical engineering applications include nanoscale fluidics, manufacturing and nano electromechanical systems (NEMS).

In functional terms, there are a range of other required skills related to nanotechnology, such as knowledge of intellectual property rights, new product/process innovation and introduction, handling and disposal of engineered nanoparticles, Research & Development management, project management, risk assessment methodologies and technology marketing.[23]

In terms of additional non-technical skills, the interdisciplinary nature of nanotechnology will likely require "soft skill" abilities in teambuilding/teamwork, intercultural understanding, communication/presentation, self-management, analytical/critical thinking, creativity, risk-taking/entrepreneurial thinking, and continuous learning[24]. The interdisciplinary aspect requires the ability to discuss technical scientific points simultaneously with engineers, biologists, chemists, physicists and doctors, where discipline-specific terms and languages are sometimes hard to overcome.

3.1 External Regulatory Landscape

Overview

PEO has recognized NME as a new discipline. PEO and the provincial and federal governments have existing regulatory frameworks for regulating the practice of engineering and it is desired to explore how these frameworks may be applied to the new discipline. There are federal and provincial regulations relating to products, processes, and workplaces, which are described below. PEO's jurisdiction is limited to regulating engineering practitioners in nanotechnology and molecular engineering.

Nanotechnology and Federal Regulatory Implications

Currently, nanomaterials are being produced, transported, and commercialized, and can be found in workplaces (see Section 3.2 on Provincial regulatory implications), consumer products, and in waste released to the environment. What will be necessary, as more products contain products of nanotechnology, is a clear communication to the public of associated risks to these substances. For some substances the health risks may not be clearly understood, and much research is ongoing in the fields of nanotoxicology, nanoecotoxicology and nanotechnology occupational health and safety.

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[22] *Nanotechnology Subsector Study: Canada's Evolving Nanotechnology Industry and Future implications for the ICT Labour Force*, Information and Communications Technology Council, June 2011, Ottawa, pp. 26-34.
[23] Ibid, p. 24
[24] Ibid, pp. 23

The effective communication of health risks of nanotechnology, which could impact the public through the foods they eat, the products they consume or their environment, will be complicated due to the inherent variation in nanotechnology products. Current information on Canadian regulations for nanotechnologies can be found at the Canadian Government NanoPortal at http://www.nanoportal.gc.ca/. Information specific to drug and health products is available at http://www.hc-sc.gc.ca/dhp-mps/nanoeng.php.

Environmental Protection

Products of nanotechnology will have widely varied properties that impact how they are dispersed in the environment, how they react with flora and fauna, and whether they would accumulate through food sources to pose a risk to human health. Within the *Canadian Environmental Protection Act*, Environment Canada has in place a procedure to examine the potential impact of new substances. Many engineered products of nanotechnology are not considered new as their structure, and not size, defines their CAS (chemical abstracts service) registry number. However, their nanoscale size will impact the material's physical properties, reactivity, transport behavior and potential toxicity. The need for unique nomenclature, to further distinguish materials with, for example, useful properties or acceptable levels of toxicity within a nanoscale size range, or based on other defining parameters, for specific nanomaterials is currently being explored in the scientific community, including joint work by ISO/TC229 and IUPAC (International Union of Pure and Applied Chemistry).

Environment Canada has also put in place the Significant New Activity (SNAc) provision whereby a substance on the domestic substances list could be imposed with notification requirements, meaning specific information pertaining to the environmental impact is required. The significant new activity would apply to material now released into the environment in either new quantities or in such a fashion that the exposure potential may be different.

Consumer Protection

Health Canada, through the *Canada Consumer Products Safety Act*, has recently received the power to recall a consumer product if it is believed that this product is linked to adverse health effects. This strengthens Health Canada's ability to protect the public by allowing it to recall the products believed to present unacceptable health risks to Canadians. Currently there are cosmetics, toys, clothing and other household products that contain or are treated with engineered products of nanotechnology. With an increasing variation in nanomaterials being incorporated into products, and as these nanomaterials are not currently labeled in consumer products, the consumer may have difficulty understanding either their added benefit or potential for health risks.

Transport of Dangerous Goods and Public Protection

Transport Canada will need to have emergency procedures in place for the transport of nanomaterials, whose chemical and physical characteristics may vary greatly from bulk phase material. The hazards presented by the products of nanotechnology will vary widely, with the chemical and physical properties dependent upon production methods and material processing, and these hazards may vary considerably from those associated to the material in its larger bulk phase. Any variation in procedures that result in the modification of the nanomaterial surface will also affect the materials properties and therefore the hazard associated to the exposure to that material. Those implicated in the transport as well as in emergency cleanup will need to be made aware of proper containment procedures or protective equipment necessary for their specific nanomaterials.

Foods, Livestock Feed and Agrochemicals

The Canadian Food Inspection Agency will need to stay aware of nanomaterials incorporated into foods, as nanoparticles may be added to modify nutrient value, or added to packaging to control freshness. Nanotechnology is also being used in agriculture, including pesticide and agrochemicals, and in livestock feeds, however much of this is still in research and development stages. Food safety is ensured by Health Canada under the *Food and Drug Act* with regulations in place that require manufacturers and importers to assess the safety of nanoproducts as additives, food or within the food packaging. For more information, see http://www.nanoportal.gc.ca.

3.2 Nanotechnology and Provincial Regulatory Implications

Of principal concern from the perspective of provincial regulatory responsibilities, is the health and safety of workers. When it comes to the exposure of workers to hazardous substances, there are currently in place occupational exposure levels (OELs) that limit the amount of a substance any worker should be exposed to. There are currently no OELs for products of nanotechnology in Ontario. In Ontario, scientists and engineers are working with products of nanotechnology, forming new materials or products sold either in Canada or elsewhere. This workforce has fallen into a regulatory gap. Since nanomaterials can be easily modified by changing their surface chemistry, forming a huge number of related materials though these materials may pose very different health risks to workers. The current method used to set OELs requires that the OEL be applied to a specific material, typically described by a CAS number. With a growing number nanomaterials formed, the process for setting OELs is challenged with materials not easily classifiable by the current system. Some companies then rely on the formation of internal OELs to protect their workers. The task of how to classify these materials in such a way that informs workers of the health risks may be addressed by the development of nomenclature for nanomaterials to adequately distinguish and identify one form of nanomaterial from another, where such distinction in addition to elemental or chemical composition may be needed for regulatory or other purposes.

Regulatory Summary

Further information and regulatory recommendations can be found in the 2008 comprehensive report *Small Is Different: a Science Perspective on the Regulatory Challenges of the Nanoscale*, developed by the Council of Canadian Academies. This report was prepared for the Government of Canada in response to a request from the Minister of Health via the Minister of Industry, and can be accessed at http://www.scienceadvice.ca/en/assessments/completed/nanotechnology.aspx. Most noteworthy is the panel's recommendation that:

> "The creation of a new regulatory mechanism to address the unique challenges presented by nanotechnology is unnecessary. They (*the panel*) did suggest that existing regulatory mechanisms can and should be strengthened. As well, the panel believes that standardized approaches for the proper handling of nanomaterials should be developed to ensure worker safety and effective

surveillance of nanomaterials' effects on consumers, workers and the environment should be carried out"[25].

3.3 Standards External to PEO

Background

Products based on nanotechnology are expected to impact nearly all industrial sectors, and will enter into consumer markets in large quantities. In the future, structural materials and composites, packaging and protective materials, devices and sensors and modeling software will evolve as large sub-sectors of nanotechnology. It is anticipated that applications in agriculture, biotechnology, health and medical, and information technology will flourish, with extensive industry and university research, and many start-up ventures underway.

The global nanotech market, in one of many market studies, is projected to account for US $1 trillion by 2020[26]. Based on current investment and patent information, the global nanotech market will likely be dominated by the United States, Japan, Germany and China, with potential of Canada building an up to 10% share, worth an estimated $100 billion by 2020. Asia-Pacific is anticipated to be the most important region for the sales of nanotech products for the near future, followed by the US and Europe.

Standards play a fundamental role in the development of this emerging technology sector. A report developed by CSA Group (Canadian Standards Association) in April 2010[27], states:

> "Governments and industry are investing in nanotechnology around the world. This needs the support of strong domestic science and effective regulation - including the development of standards for the protection of human health and the environment, while enhancing trade to support Canada's global competitiveness. Standards are essential for establishing the "rules" for the value chain from Research, Development, Prototyping, Manufacturing, Distribution, and Consumption both domestically and internationally.
>
> Standards for this evolving field cannot wait until products are in place, or be developed solely on a national basis, and then be harmonized with other countries at some future date. For nanotechnologies, a pro-active globally-based development model is being followed. Standards are being developed first on an international basis with multi-nation participation, followed by national review and adoption in Canada, when appropriate and relevant to Canadian stakeholder needs including industry, in support of both domestic and international trade."

Supporting multiple stakeholders

The National Institute for Nanotechnology (NINT), established in partnership with the National Research Council (NRC) and the province of Alberta is a leading center for nanotechnology research in Canada. Over 10 institutes of the NRC similarly have research programs with nanotechnology as a component. There is research or activities related to nanotechnologies in other federal departments including Health Canada, Environment Canada, Industry Canada, CFIA, Natural Resources Canada (NRCan). The Natural Sciences and Engineering Research

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[25] *Small Is Different: a Science Perspective on the Regulatory Challenges of the Nanoscale*, Council of Canadian Academies, 2008, Ottawa, http://www.scienceadvice.ca/en/assessments/completed/nanotechnology.aspx

[26] *Nanotechnology Research Directions for Societal Needs in 2020,* National Science Foundation, WTEC report, September 2010. http://www.wtec.org/nano2/Nanotechnology_Research_Directions_to_2020/chapter00-1a.pdf

[27] Haydon, B., *Nanotechnologies: Industry Trends and Priorities in Canada for Standards Development.* CSA Group, 2010.

Council (NSERC), the Canadian Institutes of Health Research and the Canadian Foundation for Innovation have granting programs to fund applied research in nanotech.

Nanotechnology receives mention in *Canada's Science and Technology Strategy, Mobilizing Science and Technology to Canada's Advantage*, announced in May 2007 by the federal government, which encourages a more competitive Canadian economy and improved quality of life for Canadians through science and technology. The Strategy is focused on making Canada a world leader through science & technology.

Most major Canadian universities are conducting nano-related research. Provincially-based clusters have been successful (AITF-nanoAlberta, NanoQuebec, Ontario regions and newly-formed NanoOntario) in coordinating the outputs from research labs at Canada's universities, NRC institutes and industry, to move from research to commercialization in SMEs for useful materials, intermediate and final products. Larger manufacturers may have in-house research activities in nanotechnology. Support services are growing to provide equipment, consulting, and scale-up to production requirements.

The need for standards in support of this wide mix of activities in Canada has been indicated by these groups and by industry, including the Canadian Manufacturers & Exporters (CME). Specific industry priorities in Canada for standards development in nanotechnologies were identified to CSA Standards from a representative sampling of Canada's nanotech industry in 2008 as follows:

- Product safety (for the user)
- Need for terminology (definitions) and nomenclature (unique naming systems for nanomaterials)
- Measurement methods
- Assist to mitigate public concerns about implications for health and the environment
- Toxicity/hazard potential evaluation
- Need for a risk evaluation framework (for use by manufacturers)
- Environmental protection
- Workplace safety
- Labeling (assess need first, then proceed accordingly)
- Enable trade by simplifying import/export (for example, material specifications that will provide common measurements, material grades and characteristics for global trade)

Standardization Activities

Canada, through CSA Group and SCC (Standards Council Canada), has been actively participating in the ISO and IEC to develop globally-based, science-driven standards for nanotechnology since 2005. Canada currently maintains a high profile in this work, serving as Convener for one of four international ISO Working Groups on Nanotechnologies, specifically, *Terminology and Nomenclature*. This work has placed Canada as a recognized contributor and influential voice, for this and all working group activities of ISO/TC229, *Nanotechnologies* and IEC/TC113 *Nanotechnology standardization for electrical and electronic products and systems.*

Canada's input to international standards work at ISO and IEC occurs through a multi-interest national mirror committee with more than 90 members divided into Technical Subcommittees that mirror the international committee structure at ISO and IEC. As the international standards are being written, experts from Canada provide content and input to the standard including critical review at milestone stages in development.

In addition to this international ISO/IEC work, CSA Standards has established a CSA Nanotechnology Technical Committee. A key objective for this Committee is to review and adopt relevant international ISO/IEC nanotechnology standards for use as National Standards of Canada. This committee has published in 2012 a new national standard, CSA Z12885, *Nanotechnologies — Exposure control program for engineered nanomaterials in occupational settings*. Other standards published by ISO/TC229 and adopted in Canada include *Nanotechnologies -- Nanomaterial risk evaluation* with other published international standards being considered for adoption in Canada.

Nanotechnologies-related standards work at ISO and IEC as of October 2013 covers specific topic areas including the following:

i) **Terminology** (definitions)
ii) **Nomenclature** (naming system for nanomaterials)
iii) **Measurement and Characterization** (microscopy, reference material, and metrology for characterization of nanomaterials)
iv) **Toxicity/Hazard Potential** (standards for sample preparation, toxicological assessment and screening of manufactured nanomaterials)
v) **Occupational Exposure** (standards for health and safety practices in occupational settings, control banding for occupational risk management, guidance on safe handling and disposal of manufactured nanomaterials)
vi) **Risk Evaluation and Product Safety** (including nanomaterial risk evaluation framework, preparation of MSDS for nanomaterials, and guidance on labeling of products containing nanomaterials)
vii) **Support for Commercialization and Trade** –(guidance on specifying nanomaterials, material-specific specifications; and additionally, standards in support of electrical and electronic products using nanotechnologies)

See Appendix C for list of published standards from ISO and IEC as of October 2013.

3.4 Activities outside of Canada

United States

The reader is directed to readily-available information on nanotechnologies in the United States, with much work centrally-coordinated under the U.S. National Nanotechnology Initiative (NNI: http://www.nano.gov/), with associated developing regulations under NIOSH , FDA[28], EPA and other applicable regulatory bodies.

European Union (EU)

The EU has extensive research, regulatory and commercialization activities in nanotechnologies, readily searchable on the Internet. Two resources for information are http://www.nanoforum.org/ and http://ec.europa.eu/nanotechnology/.

[28] http://www.sciencemag.org/content/336/6079/299.full

Australia

In a March 2005 report, the Australian Prime Minister's Science, Engineering and Innovation Council (PMSEIC) provided an overview of nanotechnology and its potential benefits, including potential future gains for the Australian economy. In this report, PMSEIC outlined their key findings and recommended that the Australian Government should examine options for implementation of a national strategy regarding nanotechnology that would ensure —an appropriate regulatory framework which safeguards the health and safety of Australians.

A National Nanotechnology Strategy Taskforce (NNST) was established within the Department of Industry, Tourism and Resources in July 2005. The NNST taskforce delivered their report outlining "Options for a National Nanotechnology Strategy" to the Australian Government in June 2006.[29]

The Australian Office of Nanotechnology (AON) was subsequently created to drive implementation of the National Nanotechnology Strategy. The AON, which is based within the Department of Innovation, Industry, Science and Research, is the coordinating body charged with ensuring a consistent approach to nanotechnology issues across government departments.

Following from the NNST recommendation regarding nanotechnology regulation, a contract to conduct an independent study of the possible impacts of nanotechnology on regulatory frameworks was awarded in January 2007 to members of the Monash Centre for Regulatory Studies within the Faculty of Law at Monash University.

The Monash Report[30] concluded that although there was no immediate need for major changes to the regulatory regimes, there were six areas of potential concern regarding regulatory issues for nanomaterials. These regulatory issues are very similar to those raised the EDTF NME group.

Engineers Australia have also discussed and promoted public awareness of nanotechnology. Their conclusions regarding the need to be proactive in safeguarding public safety are very similar to those of this group.[31] Engineers Australia, in recognition of the critical importance of this new field of engineering, established a National Committee on NanoEngineering in 2007. The Committee was formed with expert representatives from the research and academic community, industry and government. The Panel

> "aims to serve the engineering profession by disseminating the knowledge and technical know-hows of nanoscience, nanotechnology and nanoengineering; by providing an information hub for

[29] Regulatory Governance Initiative, Pelley, J., and Saner, M., "International Approaches to the Regulatory Governance of Nanotechnology", http://www.regulatorygovernance.ca/sites/default/files/publications/Nanotechnology_Regulation_Paper_April2009.pdf

[30] Ludlow K., Bowman D.M. & Hodge G.A. (2007), *Final Report: Review of Possible Impacts of Nanotechnology on Australia's Regulatory Frameworks*, Melbourne: Monash Centre for Regulatory Studies, Monash University

[31] Payne, Simon, Engineers Australia, "Nanotechnology", http://www.engineersaustralia.org.au/sites/default/files/shado/Learned%20Groups/National%20Committees%20and%20Panels/Nanotech/Newsletters%20and%20Publications/Ethical%20Challenges%20in%20Nanotechnology.pdf

> the timely developments and events; liaising with international and domestic professional bodies and governmental agencies; and promoting education in the field."[32]

Engineers Australia has recognized Nanotechnology Engineering as a discipline since 2008, and accredited a Bachelor of Engineering degree program at University of South Australia in "Mechanical and Nanotechnology Engineering".[33]

Other International

The Russian Federation and Asian countries, near and far east are heavily committed to nanotechnologies. A useful resource for the Russian Federation is http://www.rusnano.com/. Information for many Asian countries can be found at http://asia-anf.org/. Many other countries are similarly involved in nanotechnologies with associated regulatory and standards development activities.

The OECD is involved in coordinating research and laboratory protocols for the regulatory needs of it member countries, with information at http://www.oecd.org/; search on WPN (Working Party on Nanotechnology) and WPMN (Working Party on Manufactured Nanomaterials). Canada's federal government participates in this work.

3.5 Bioprocessing Regulations in the Biopharmaceutical industry

Background

Biopharmaceuticals are drugs that are produced using biotechnology. They are derived from living organisms that have been bioengineered through techniques such as recombinant DNA technology where genetic material from multiple sources (sometimes different species) is brought together. An example is recombinant human insulin, where the insulin is produced from engineered E. coli bacteria.

One similarity between biopharmaceuticals and nanomaterials has been the spread of techniques used and products made. An example of such a technique is recombinant DNA and RNA technology, being applied to produce many different products including food ("golden rice" and other genetically modified plants) and food products/additives (microbially produced rennet equivalent used in cheese making). This would imply that the basic technology involved in biopharmaceuticals is an enabling technology, similar to nanoengineering.

There has been rapid growth in biopharmaceuticals and related products beginning in late 1970's up until the present, which is similar to the growth rate expected for the nanotechnology market.

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[32] Engineers Australia, National Committee on NanoEngineering http://www.engineersaustralia.org.au/sites/default/files/shado/Learned%20Groups/National%20Committees%20and%20Panels/Nanotech/Sponsorship%20Prospectus.pdf

[33] Engineers Australia, Australian Professional Engineering Programs Accredited, 2012. http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/latest_be_programs_jan12.pdf

Regulation of Biopharmaceuticals

Regulation of biopharmaceuticals is similar to standard drugs, with very little attention paid to the techniques used to produce them other than application of GMP (Good Manufacturing Practices) typical for existing drugs. Little has changed in the regulatory pathway for manufacturing methods but there have been very recent changes in regulations that control the approval for biopharmaceuticals.

Both the FDA and the European Medicines Agency (EMA) have recently introduced guidance and regulation regarding toxicity (both animal and human) studies. The recent (2012) FDA documents include:

- Scientific Considerations in Demonstrating Biosimilarity to a Reference Product[34]
- Quality Considerations in Demonstrating Biosimilarity to a Reference Protein Product[35]
- Biosimilars: Questions and Answers Regarding Implementation of the Biologics Price Competition and Innovation Act of 2009[36]

These documents are mostly concerned with details regarding biosimiliarity between existing drugs and/or products and proposed biopharmaceuticals that are intended to produce a similar effect. These guidance documents outline regulatory pathways for approval of new biopharmaceuticals that seek to both accelerate approval by better defining the process while also seeking to improve safety by ensuring a totality of evidence is used to assess biosimilarity.

Similarly the EMA's guidance document "Guideline on Similar Biological Medicinal Products Containing Monoclonal Antibodies"[37] contains steps for risk-based approach to evaluate new biopharmaceuticals including clinical safety. The document also outlines where extra vigilance will be used to monitor the safety of new biopharmaceutical products. This document is part of EMA's family of guidance documents that cover EPO, GC-SF, insulin and interferon-α.

Where the basic technology has been applied to products other than drugs there are typically multiple regulatory agencies involved in approving them for use. This area of research is rapidly evolving including recent work in genetically modifying tobacco to produce interleukin-10 (IL-10), a potent anti-inflammatory cytokine.[38] Since the products are not produced in a true laboratory or manufacturing setting, the regulatory pathway is complex and most approval agencies now reserve the right to apply more stringent measures to applications.

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[34] http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/UCM291128.pdf

[35] http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/UCM291134.pdf

[36] http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/UCM273001.pdf

[37] www.ema.europa.eu/ema/pages/includes/.../open_document.jsp?

[38] Science News, 2009. "Tobacco Makes Medicine". http://www.sciencedaily.com/releases/2009/03/090318211236.htm

Biopharmaceutical Regulations and Nanomaterials

It is interesting to note that regulatory agencies are now in the process of evaluating whether new guidance for biopharmaceuticals that contain nanomaterials should be introduced. The agencies appear to be aware of serious gaps in the regulations including the following statement from a recent report:

> In the case of medical devices and pharmaceuticals products, the existing provisions, due to the detailed authorization procedures required in this field, are generally considered adequate for nanorelated products, although a case by case approach in the evaluation and authorization procedures is envisaged to take into account the peculiar properties of nanotechnologies [OBS1, OECD1]. One issue is the blurring of regulatory boundaries for advanced nanorelated technologies, such as in the case of nanomedical products combining diagnostic and therapeutic functions or products where the nature of the primary mode of action is not clear. Authorities are active in following the state of the art, discussing the consequences of developments in nanomedicine for risk assessment, and are developing guidance.[39]

The conclusion in this report is the following: "The prevalent position amongst authorities and industries is that existing legislation, adapted for nano related products, is able to deal with the risks potentially associated with them."[40] This position is matched in the EU staff working paper "Types and uses of nanomaterials, including safety aspects"[41].

Similarly FDA released two guidance documents in 2012 that reach a similar conclusion (Draft Guidance for Industry: Safety of Nanomaterials in Cosmetic Products[42] and Draft Guidance for Industry: Assessing the Effects of Significant Manufacturing Process Changes, Including Emerging Technologies, on the Safety and Regulatory Status of Food Ingredients and Food Contact Substances, Including Food Ingredients that are Color Additives[43]).

Conclusion and Recommendations

The general consensus among regulatory agencies is that present product regulations governing the approval of new biopharmaceuticals are sufficient to ensure the safety of the products even with the possibility that new types may contain nanomaterials. However, since these regulatory agencies concede that the field is growing rapidly and nanotechnology is very new, it is recommended that PEO-licensed engineers closely monitor developments in this field for new safety requirements.

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[39] Observatory Nano report, "Developments in Nanotechnologies Regulation & Standards – 2012", April 2012. http://www.observatorynano.eu/project/filesystem/files/ObservatoryNano_Nanotechnologies_RegulationAndStandards_2012.pdf

[40] ibid.

[41] European Commission, Staff working paper "Types and uses of nanomaterials, including safety aspects", 2012. http://ec.europa.eu/nanotechnology/pdf/second_regulatory_review_on_nanomaterials_-_staff_working_paper_accompanying_com(2012)_572.pdf

[42] http://www.fda.gov/downloads/Cosmetics/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/UCM300932.pdf

[43] http://www.fda.gov/downloads/Cosmetics/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/UCM300927.pdf

Recommendation for Practitioners:

The EDTF-NME group recommends that NME practitioners be regularly informed of new regulations, codes and other legislations for nanomaterials, and, that such developments be posted on PEO's web site for general public access.

Recommendations:

That PEO-licensed engineers closely monitor developments in the biopharmaceutical field for new safety requirements.

4 PEO Licensing Considerations

4.1 Product Regulations vs. Licensure

The previous section provides a good example of product-related ”regulations”. The word “regulation” is a generic term whose meaning must be inferred from context. In this report we have a double meaning for the use of the term. Many, in general, speak of regulations to mean Product Regulation similar to those in section 3.5. Professional Regulation, or Licensure, is our primary concern in this report. These two nuances of the same word must be kept clear. Government product regulations (GPR’s) are often seen as encumbering industry and reducing their efficiencies, although they may in fact substantially improve public safety and protect the environment. Broadly speaking there are two tools that can be used to enhance public protection. These are:

1. Specific Government Product Regulations, (GPRs) and
2. Licensing an occupation

This sub-section sets out the differences in these two meanings of ‘”regulation”. GPR's are aimed at constraining enterprises or individuals to behave in certain ways. For example, a regulation may specify the maximum arsenic concentration allowed in an effluent. Exceeding this limit breaks the law and exposes the law breaker to the prescribed penalties. As science learns more about arsenic, the concentration limits allowed may change. Furthermore, the concentration limit of a totally new substance is not limited and it may in fact be far more dangerous. Red Dye food colouring is one good example from the USA. We now have Red Dye # 40, with the previous versions found to be carcinogenic AFTER being released into the market for several years each. There are many examples of 'product' type regulations with long time delays before their harmful effects on humans and/or the environment were understood. CFC's, Tobacco smoking and DDT are other well known examples.

A licence is aimed at controlling who has permission to perform specific activities. It would be possible for example, to license individuals to release effluents into public water ways. It would then be the responsibility of this person to ensure that the effluent was not toxic to humans or to the environment. This would cover all compounds in the effluent - not just arsenic, even ones not yet invented. It would be reasonable for the government to expect that such a licensed person would exercise their best judgment in protecting the public welfare. Clearly such a person must prove they have the knowledge to be able to exercise such judgment.

Given the accelerating pace of change (see section 4.2 below) within science and technology, there is even greater pressure for a quick response. Waiting, for perhaps years, to determine the hazards of a new product is no longer acceptable. Within NME, the potential risks to the public welfare are too important.

If a professional can be called upon to protect the public interest, then the need for complex technical GPR's is significantly reduced, increasing public confidence.

Such licensing legislation restricts actions to “Qualified Persons” who are knowledgeable in the field under review. This results in much greater freedom for policy makers and much faster reaction times.

In our case with the Engineering Licence, we have even more control in that engineers often design the products and the processes to make products. It is the responsibility of such design engineers to ensure that the public interest is both served by the new works and is protected from harm by such new works. In essence, the engineer practitioner is in a position to be proactive to ensure that dangerous products or processes are not released.

4.2 Accelerating Pace of Change

"*As we move into the 21st century, we come from a remarkable past century of amazing technological progress. Yet this pace of change is not slowing down. If anything, it is accelerating. It appears that each new scientific discovery raises several new avenues for discovery."*[44]

This accelerating change has direct implications for both NME with respect to new products released on the public, and, for PEO as it attempts to govern and license all new forms of engineering that have a significant "public interest (well-being)" impact.

Consider the following example of the pace of change. In 1970, it cost $150,000 to transmit 1 trillion bits of information (a small library). By 1999, this cost dropped to 12 cents![45]

Emerging Disciplines represent the profession's most significant challenge at all levels. As time moves on, the issues will compound, stretching our abilities as humans to govern this ever expanding profession.

In the mean time, practices like NME will follow the same accelerating trends in the numbers of products produced and their varied risks.

The high speed growth of technology means a plethora of new products. It will be impossible for product regulations to handle these fast enough particularly since such regulations are overwhelmingly after the fact. Only properly licensed practitioners are in a skilled and ethical position to assess the potential risks of a new product or manufacturing process before exposing members of the general public to these.

We must have NME licensing to ensure the public safety. See Appendix G - The Accelerating Pace of Change for more details on this subject.

4.3 PEO Processes

We will now turn our focus to Professional Regulation or Licensure and its detail meaning. PEO's principal object, as found in section 2(1) of the Professional Engineers Act, is

> ..to regulate the practice of professional engineering and to govern its members, holders of certificates of authorization, holders of temporary licences, holders of provisional licences and holders of limited licences in accordance with this Act, the regulations and the by-laws in order that the public interest may be served and protected:.

Its additional objects in section 2(2) that cover regulatory activities include;

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[44] DeVita, Peter, P.Eng. A Search for Advocacy – Creating the Canadian Engineering Profession, G7 Books, 2013, p. 51

[45] Prof. Michael M. Tseng Federal Reserve Bank of Dallas Vertical Industry Structure and Integral Product The Bank Credit Analyst 2004.28

1. To establish, maintain and develop standards of knowledge and skill among its members.
2. To establish, maintain and develop standards of qualification and standards of practice for the practice of professional engineering.
3. To establish, maintain and develop standards of professional ethics among its members.

For PEO to be able to effectively regulate the professional activities related to NME, it must clearly lay out its intended scope within those activities, and establish the relevant academic and experience requirements, also, where necessary, professional practice guidelines or standards, and continuing education requirements.

Council Processes for Policy Implementation

Past President R. Braddock chaired the Council Policy Decision Database Task force which reported to Council meeting C444 on Dec 17, 2007. This report assessed Council motions and policies passed from 1984 to 2005. It found several Council decisions had passed and had not had any implementation. In general, the task force found that Council had no mechanism in place to allow Councillors to track activity. The report made several specific recommendations to deal with unimplemented policies as well as a recommendation to set up database of Council policy motions along with links to all supporting reports. In particular, access to the reports behind the decisions was important for Councillors to understand the thinking process at the time. It was recommended and accepted by Council that both the policies passed and bank of reports were to be kept on-line and easily accessible by at least the Councillors. Since such motions, policies and reports are a matter of public record there is no reason to restrict access so these should be available to all PEO members and the general public.

In order for PEO Council to progress, it (Councillors) must be able to see where we have been. There is no point to retreading history. If a Council wishes to set a new directly let it be so with the knowledge of what it is consciously changing. These same considerations apply to all of the EDTF recommendations. We therefore recommend as stated below.

Recommendation

That PEO Council direct the Registrar to create an administrative plan within 3 months of approval of this recommendation that is to be approved by Council, that will permit Councillors to access and track approved initiatives of Council along with their current implementation status.

4.4 Academic Requirements

Applicants

All successful applicants for licensure by PEO must demonstrate that they have acquired the requisite academic knowledge.

P.Eng. Licence applicants

Applicants for a Professional Engineer (P.Eng.) licence must have a bachelor's degree in engineering from a Canadian university program accredited by the Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers (CCPE), or equivalent academic qualifications.

CEAB Accredited Program applicants

These applicants are deemed to have met their academic requirements by virtue of having a bachelor's degree in engineering from a CEAB-accredited program, without further examination. At this time, the University of Waterloo's Nanotechnology Engineering program is the only engineering program in this area that has been accredited by the CEAB. Since 2010, approximately 152 people have graduated from this program.

Non-CEAB Programs (domestic and international)

If an applicant's bachelor's degree in engineering was obtained from a non-CEAB-accredited program, whether in Canada or abroad, their qualifications will be assessed against the CCPE's Canadian Engineering Qualification Board (CEQB) criteria in the applicant's engineering discipline.

Applicants without an undergraduate degree in engineering from a program accredited by the CEAB, will have their academic background assessed by PEO to determine whether it is equivalent to the established standards. PEO will assign technical exams to give applicants an opportunity to confirm (Confirmatory Examination Program) that their academic preparation is equivalent or to remedy any identified deficiencies (Specific Examination Program).

Applicants who have been assigned a Confirmatory Examination Program and have more than five years of engineering experience may be granted an interview with its Experience Requirements Committee (ERC) to determine if their experience provides any basis to warrant exam relief.

The minimum educational level stipulated by Regulation 941 under the *Professional Engineers Act* for a licence is:

- a bachelor's degree in an engineering program from a Canadian university that is accredited to the Council's satisfaction; or
- equivalent engineering educational qualifications recognized by the Council

If an applicant's overall academic preparation is assessed by PEO as not meeting the minimum level stipulated by legislation, they may be assigned a Specific Examination Program. However, applicants with more than 10 years of overall engineering experience will be invited to attend an interview with PEO's Experience Requirements Committee (ERC) to determine if their experience provides any basis to warrant exam relief.

Limited Licence Applicants

A limited licence is issued to an individual who, as a result of at least 13 years of specialized experience, has developed competence in a certain area of professional engineering.

Regulation 941, amended to O. Reg. 692/00, sections 45 and 46 states:

45. The following conditions apply to every limited licence:

1. The practice of professional engineering by the holder of a limited licence must be limited to the services specified in the limited licence.
2. When the holder of the limited licence ceases to provide the services specified in the limited licence, the holder must notify the Registrar, and return to the Registrar the limited licence and the seal issued to the holder. R.R.O. 1990, Reg. 941, s. 45.

46. The academic requirements and qualifications for the issuance of a limited licence are:

1. One or more of the following:
   i. A three-year diploma in engineering technology or a Bachelor of Technology degree in engineering technology from an institution approved by the Council.
   ii. A four-year honours science degree in a discipline and from a university approved by the Council.
   iii. Academic qualifications accepted by the Council as equivalent to a diploma or degree mentioned in subparagraph i or ii.

With respect to the academic qualifications for a limited licence, the NME Group recommends that an Honours Bachelor of Science degree in the field of physics, chemistry, microbiology, biochemistry, molecular biology, or genetics is the minimum requirement to prepare for a limited licence to work in the field of Nanotechnology and Molecular Engineering (NME).

A recent report from the Information and Communications Technology [Sector] Council (ICTC) identifies ten non-engineering nanotechnology programs, namely five Bachelors of Science degrees, one diploma and four Masters of Science degrees that could provide the necessary academic training for nanotechnology.[46]

Recently, PEO's Joint Engineering and Natural Science Task Force developed a policy to assist with regulation and licensure of practitioners with a natural science background where necessary. The Task Force made two recommendations for further work[47] and it is expected that there will be a path for licensure for those natural scientists practicing engineering. An Overlapping Practices Committee was established by Council in February 2011 with the following mandate:

> Where the Registrar believes that a recognized natural scientist may be practicing professional engineering without a licence, limited license or temporary and/or without a certificate of authorization, the Committee will consider the matter and make recommendations to assist the Registrar and the natural scientist to resolve the matter prior to the Registrar proceeding with any enforcement action to the courts.[48]

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[46] *Nanotechnology Subsector Study: Canada's Evolving Nanotechnology Industry and Future implications for the ICT Labour Force*, Information and Communications Technology Council, June 2011, Ottawa, p. 39. http://www.ictc-ctic.ca/content_2col.aspx?id=1559

[47] PEO, Joint Engineering and Natural Science Task Force Final Report, 2011 http://www.cap.ca/sites/cap.ca/files/jenstf_final_report_-_feb_11.pdf

[48] http://www.peo.on.ca/Committees/OPC/OPC.html

Alternatively, a nanoscientist could seek to obtain a P.Eng. licence by taking ARC-assigned confirmatory courses and exams to demonstrate equivalent levels (breadth and depth) of knowledge.

Current Professional Engineer Practitioners Entering NME Discipline

Engineering is by definition an evolving profession, due to rapidly changing scientific discoveries and the continual introduction of new materials, technology and processes. The successful practitioner must make every effort to stay current with those developments, and their potential application to engineering projects.

At the same time, there is a parallel pattern of overlap or convergence between different engineering disciplines, through the innovative application of hybridized or crossover approaches. In fact, some of the 30 current engineering disciplines are themselves an expansion of existing disciplines or a combination of one or more areas of engineering, for example, biomedical/ biochemical engineering and agricultural/bioresources/biosystems/food engineering.

In the Phase 1 report, NME was characterized as a horizontal engineering discipline, incorporating in part elements from diverse fields as chemical, materials, biomedical, and electrical engineering. Since to this point in time, PEO has not licensed any individuals in NME, any currently licensed and practising P.Eng. could theoretically migrate to practice in the NME area so long as they are competent to do so. The definition of "professional misconduct" in section 72(2)(h) of Regulation 941 includes "undertaking work the practitioner is not competent to perform by virtue of the practitioner's training and experience".

Thus, all practitioners have a responsibility to practice only within fields in which they are sufficiently competent by virtue of their demonstrable training and relevant experience. Practising outside of such area of competency could result in a finding of professional misconduct and further disciplinary sanctions.

While the P.Eng. licence that PEO provides to a qualified applicant is generic, the examination of the applicant's relevant education and experience qualifications is quite specific to their area, and in some cases, sub-areas of engineering disciplines. If a licence holder wishes to practice professional engineering in a discipline different from that which they were assessed at the time of licensure, they may do so only if they believe that they have the relevant training and experience in that area.

In contrast to PEO's discipline-specific qualification determination at the point of initial licensure, PEO policy requires a licensed P.Eng. to self-assess their competency to practice in another area. Thus it is up to the licensed P.Eng. to; acquire the necessary training and experience in the other area; determine how they will assess their technical competency; and assess whether they are competent.

To do so, the practitioner must first determine what training and experience in the new area is desired, available and sufficient. They must then determine how best to self-assess, and finally, do the assessment. Currently, there is no external requirement for examination, peer review or other mechanism. PEO does not collect statistics on what areas of engineering are being practiced by its licence holders that differ from the initial licensure, however recently it has added information on engineering discipline currently practiced, as provided voluntarily to PEO by the licence holder.

Without engaging in a debate about the current PEO policy with respect to practicing in other areas of competency, the question for NME is whether it is necessary or desirable to impose any specific restrictions on current P.Eng.'s to practice NME, compared to any other engineering discipline.

One possible rationale for imposing some form of qualification for NME would be its sheer novelty, both in terms of scale (at the molecular level) and the processes involved. Another possible, if complementary, rationale is the potential, unknown risk to human health accruing from nanomaterial applications. The Phase 1 report (pp. 15-16) and section 2 of this report dealt with the difficulties of detecting and disposing of nanomaterials, as well as their potential biotoxicity. This would suggest that a higher entry threshold should be set for NME to ensure competent practice.

The counterpoint to this argument is that the specialization and resources required for NME research and application by definition limit one to a very narrow set of facilities for practicing NME. NME is not something that can be practiced as a simple adjunct to one's engineering practice, as might be the case with, for example, civil, mechanical or electrical engineering. Most NME research is being carried out in universities or industry with their own internal qualifications and safety controls. For example, the University of Waterloo's Nanotechnology Engineering program requires that all graduates of the program receive training on the potential health risks of nanotechnology through the lifecycle of products, as well as how this could impact workplace practices. Commercialization is still in its infancy in Ontario, typically in specialized laboratories or manufacturing facilities. Simply put, one cannot "dabble" in NME as an adjunct practice. Whether PEO should rely on universities' or industry's entry requirements remain to be discussed further.

Assuming that PEO determined that some level of NME qualification was necessary for current P.Eng.s licensed in other engineering disciplines, the next policy question would be whether the assessment should be voluntary or mandatory. Under a voluntary model to self-assessment, methods such as reviewing the NME Core Body of Knowledge and syllabus (found in the Phase 1 Report), using any of the relevant Professional Practice Guidelines or Standards (see section 4.6 of this report) or the ARC board sheet for NME based on the syllabus could be used. Even the voluntary use of one of these source documents would represent a precedent for PEO.

Under a mandatory model, peer review or technical examinations could be used to assess NME qualifications. This would represent a very different approach from PEO's current model and would set a precedent that would have to be applied to all other situations where a P.Eng. wishes to practice in a different discipline than that which they were educated and gained experience. While the Academic Requirements Committee could possibly carry out the assessments, it would add resourcing costs.

It is our opinion that while there are certain heightened risks to practicing NME, the technical safety standards already in place within the university or private sector research laboratories would provide sufficient quality assurance before a P.Eng. begins to practice in the NME field. Therefore a mandatory pre-qualification model is not justified at this time, and a voluntary one should be sufficient.

Recommendations:

That Council directs the Academic Requirements Committee within six months to create a board sheet for NME, using the CEQB Nanotechnology Engineering Syllabus found in Appendix B of the Phase 1 report. [enhanced phase 1]

That Professional Engineers not previously licensed in NME who wish to practice in this area refer to the Core Body of Knowledge, Professional Practice Guidelines and/or the ARC board sheet to determine the technical knowledge requirements for NME practice in order for their self-assessment of competency to begin practicing in the field.

4.5 Experience Requirements

P.Eng. Experience Requirements and PEO's Assessment Process

All applicants for a professional engineer licence:

- are required to demonstrate 48 months of verifiable acceptable engineering experience gained following graduation;
- are eligible to receive credit of up to 12 months of pre-graduation experience toward the 48 months of required experience;
- normally receive credit for the successful completion of postgraduate engineering degree(s) from a PEO-recognized university; and
- must acquire at least 12 months of acceptable engineering experience in a Canadian jurisdiction, under a licensed professional engineer (P.Eng.). This experience must be in addition to that obtained at the pre-graduation stage and/or toward a postgraduate degree.

The typical process involves the applicant submitting a completed application detailing their 48 months' worth of engineering experience in their discipline, accompanied by two references by a P.Eng. who supervised their work. The completed information is then reviewed by PEO staff, and if necessary, by an interview with a panel of P.Eng. licence holders with technical expertise in that discipline, who will assess if the experience requirements have been met for the purposes of granting a licence to practice professional engineering.

The PEO Experience Requirements Guide defines acceptable engineering experience criteria as the following:

1. Application of Theory
2. Practical Experience
3. Management of Engineering
4. Communication Skills
5. Social Implications of Engineering

NME is an emerging technology and, as such, has not established a history of characteristic practice similar to established engineering disciplines. NME is also a complex discipline due to its very diverse range of applications. Therefore, it is difficult at this time to develop a 'standardized' set of experience requirements for practitioners of NME. The horizontal nature of the field of NME means that likely applicants will have experience from across a number of different areas.

There are some fundamental experience requirements that the EDTF NME group feels are applicable to typical applicants. Appendix H - NME Experience Requirements Criteria is intended as a guideline to the PEO Experience Requirements Committee to assist in assessing NME applicants' experience for application of theory, practical experience and social implications of engineering. NME applicants should have some core experiences in these areas. This document may also assist ERC in determining selection of committee experts.

Recommendation:

That Council directs the Experience Requirements Committee to review and adopt within six months the proposed experience requirements for NME as contained in Appendix H of this report as they pertain to the five criteria.[enhanced phase 1]

Experience requirements for Limited Licence

The experience requirements for a limited licence are detailed in section 46, paragraph 2 of Regulation 941, as being the following.

2. Thirteen years of experience in engineering work acceptable to the Council, including the years spent in obtaining the post-secondary academic training referred to in the above paragraph with at least one year of such experience under the supervision and direction of a member or members or under the supervision of a person authorized to practise professional engineering in the province or territory in Canada in which the experience was acquired and at least the last two years of the experience in the services within the practice of professional engineering with respect to which the limited licence is to apply.

An applicant for a limited licence follows the same application process as for a P.Eng. licence, however, their extent of required work experience would be tightly restricted to their intended area of practice. Accordingly, a limited licence applicant's required work experience would be a relevant subset of the requirements listed above for a P.Eng. applicant.

It must be recognized that the current experience requirement for a limited licence is based on engineering work supervised by a P.Eng. While this is entirely appropriate within an engineering environment, the model does not apply to non-engineering work experience. An individual may be working in nanoscience fields without practising any engineering or being supervised by a P.Eng.,and thus would never be able to qualify for a limited licence in NME.

PEO has a regulatory imperative under the Act to ensure that anyone practising professional engineering, even in a limited scope, is licensed to do so. As such, there must be a regulatory means by which a person can actually achieve a limited licence, and to not do so would create a double-jeopardy situation. We therefore recommend that section 46 of Regulation 941 be amended to allow for non-engineering work experience to be assessed for its application to the appropriate limited scope. While we cannot specify the mechanism at this time, PEO's current efforts to address the limited licensing of natural scientists should be reviewed for applicability to NME limited licences.

Recommendation:

Council directs the Legislation Committee within six months to consider amending section 46 of Regulation 941 to provide a mechanism for non-engineering work experience that would be relevant to an application for a limited licence similar to that being examined for Natural Scientists.

4.6 Professional Guidelines and Standards

Through its Professional Standards Committee (PSC), PEO develops guidelines to aid engineers perform their engineering role in accordance with the *Professional Engineers Act* and Regulation 941, for the following reasons;

1. Guidelines define what engineers should do with respect to specific professional services they provide. They are not intended to be short courses in an engineering subject.
2. Guidelines provide criteria for expected practice by describing the required outcome of the process, identifying the engineer's duty to the public in this particular area of practice, and by defining the relationships and interactions between the various stakeholders (government, architects, other engineers, and clients).
3. Guidelines add value to membership and public by establishing criteria for professional standards of competence.
4. Guidelines communicate the role of the engineer to the public by clarifying the objective of the practice and what is expected of engineers engaged in this particular task. By demonstrating that the task requires specialized knowledge, higher standards of care, and responsibility for life and property, the public perception of engineers as professionals is reinforced.
5. Where appropriate, alternative media such as practice bulletins are used for urgent issues or where short document shelf life is expected. Bulletins are also used for interpretations or supplements to the guidelines. Development of bulletins are governed by the same criteria imposed on guidelines. Where appropriate bulletins are incorporated into guidelines at the earliest opportunity.

PSC uses the following elements in assessing need for a guideline:

a) number of members affected by practice
b) impact on public
c) number of enquiries made to PEO about practice
d) required by creation or amendment of legislation
e) change in Professional Engineers Act or its Regulations
f) demonstration through the existence of disciplinary cases indicating common misconceptions of engineers' responsibilities that a coherent, consistent standard of practice in a particular area is required
g) direction of Council

In the case of NME, section 2, the NME Subgroup has identified the public safety risks that may occur from the development or use of engineered nanomaterials, due in part to their difficulty of detection/measurement and possible end-of-lifecycle decay. This addresses the "impact on public" criteria. The novelty of the NME discipline suggests that most of the professional engineers migrating to work in this field have been educated and have acquired work experience in other engineering disciplines (e.g. chemical engineering, engineering physics, biomedical engineering). The development of a professional practice guideline will assist in clarifying the technical knowledge and standards, and professional obligations necessary for ethical practice in the NME discipline or fields of activity.

It is envisioned that Professional Practice Guidelines for NME would encompass the following areas:

- A definition of the Scope of Practice and potential activities in addressing the scope (Executive Summary section of this report)
- Identification of the potential risks to human health from non-professional practice (section 2 of this report)

- Reference to the NME Core Body of Knowledge (as detailed in the Phase 1 report.)
- Identification of the applicable international and industry standards, federal and provincial legislative and regulation requirements applying to NME (section 3 and Appendix C of the Phase 2 report.)
- Identification of Professional Practice throughout the nanoproduct's lifecycle, including laboratory design, development, and testing, commercial fabrication, handling/shipping, and safe disposal of end-of-cycle nanomaterials.

Recommendation:

That Council direct the Professional Standards Committee within six months to draft a professional practice guideline for NME for reference by P.Eng.s wanting to enter into NME practice. EDTF recommends that the following elements contained in this report be included in the guideline:

a. *a definition of the Scope of Practice and potential activities in addressing the scope (Executive Summary of this report);*
b. *identification of the potential risks to human health from non-professional practice (section 2 of this report);*
c. *reference to the NME Core Body of Knowledge (as detailed in the April 2010 Phase 1 report);*
d. *identification of the applicable international and industry standards, federal and provincial legislative and regulation requirements applying to NME (section 3 and Appendix C of the Phase 2 report); and*
e. *identification of Professional Practice throughout the nanoproduct's lifecycle, including laboratory design, development, and testing, commercial fabrication, handling/shipping, and safe disposal of end-of-cycle nanomaterials.*

4.7 Compliance Considerations and Proposals

NME is a new practice filled with both great promise and potential risk. PEO has a responsibility to the public to ensure that only qualified individuals practice NME so that the public interest is served and protected. This means that both rigorous licensure and compliance/enforcement activities take place. PEO's Council in January 2005 passed an enforcement policy which states that PEO will take action against individuals or entities who are not licensed but are practicing professional engineering, or who offer professional engineering services to the public. In addition, PEO enforces against those who may misrepresent themselves as professional engineers, or use the reserved titles defined under Section 40 of the Act.

Enforcement (compliance) action taken by PEO can range from a simple letter directing compliance with licensing and Certificate of Authorization (C of A) provisions of the Act, up to and including legal proceedings against offenders. The restrictions on who may practice professional engineering or engage in the business of providing professional engineering services to the public, together with exceptions, are found in section 12 of the Act. This is set out two regimes: Licencing and Certificate of Authorization. The legal remedies available to PEO against persons or entities that violate the Act are found in Sections 39 and 40 of the Act.

All inquiries and complaints received are reviewed and investigated by staff. A determination is made as to whether the enquiries/complaints are a matter of concern to the PEO in that they constitute a violation of the Act. PEO's policy in matters of concern is to contact the offenders, advise them as to the enforcement provisions of the Act, give them "a reasonable chance to comply" with the legislation and negotiate a satisfactory settlement. Legal proceedings are only utilized as a last resort where there is no cooperation from the offenders and where there is compelling evidence of an offence. In cases which are clear violations of the Act, and evidence is available (i.e. good documentary evidence and/or convincing witnesses), PEO's policy is to commence legal proceedings without delay.

Since PEO is embarking on regulating the new NME discipline, it must provide fair advance notice to individuals and companies who might currently be practising NME. Before proceeding with enforcement activities for practicing without a licence, PEO will provide the opportunity to apply for licensure (either as a P.Eng. or a Limited Licence holder). We must now consider how to determine a suitable grace period for compliance.

One example arose during the discussions on one of the industrial exceptions. At the April 13, 2012 Council meeting, PEO Council approved a maximum 12-month period of waived enforcement against companies who will not be in compliance by the proclamation date but who have submitted to PEO an approved compliance plan. Individuals who are currently doing NME engineering work will need to apply for either a P.Eng. or Limited Licence.

We therefore recommend that PEO communicate with universities and industry on the introduction of NME regulation to allow non-engineers the opportunity to apply for an appropriate Limited Licence or to qualify for a P.Eng. Licence. It is further recommended that PEO refrain from initiating any enforcement action against unlicensed NME practice for at least one year from the commencement of its communication activities.

Recommendations:

That Council direct the Enforcement Committee to use the proposed Scope of Practice for its regulatory enforcement activities.

That Council direct the PEO Enforcement Committee to create an enforcement plan, to be initiated one year from date of Council's NME motion, to allow for individuals to qualify for a P.Eng. or Limited Licence in NME.

That PEO Council direct the Enforcement Committee to investigate within six months ways and means so that PEO can use the courts to establish 'Common Law' rulings that support these recommendations;

4.8 Stakeholder Feedback to the Phase 2 report

Subsequent to this report, this group will conduct stakeholder consultation and report back to Council on any issues or concerns. This will be drawn from the organizations listed in appendix A.

4.9 Communications and Public Education Plan

All new engineering practices must be promulgated to ensure that the public is aware the PEO will license the new practice to ensure that the public is protected. This is no different than the creation of a new law by a legislature. It must be publically declared so the public knows there are new rules.

Proclaiming a new engineering field with new 'exclusive rights to practice' has the same impact as a new law from the legislature. Hence the public must be made aware of its existence.

Recommendation:

The EDTF-NME group recommends that PEO communicate with universities and industry on the introduction of NME regulation to allow non-engineers the opportunity to apply for an appropriate Limited Licence or to qualify for a P.Eng. Licence.
Action: staff to proceed per Council direction.

4.10 Establishing Rights to Practice

This section contains key ideas as to how rights to practice are established. This section will be of particular interest to the Legislation Committee, the Enforcement Committee and the Professional Practice Committee.

Rights to Practice in NME

Legislation and Common Law (court precedence) are methods for creating the legal framework that effects a 'closed occupation', and defines the 'exclusive' rights to practice. The power derived from legislation that ensures that the license which defends the rights to practice and protects the security and prosperity of the public. The following section provides details regarding these concepts and how they impact PEO in carrying out its mandate.

Supply Side Legislation

PEO already has legislative authority via the *Professional Engineers Act* in Ontario. This is the 'supply side' authority that creates the Licensing regime and supplies the practitioners. The act gives PEO strong policing powers to stop the illegal practice of engineering, such as the ability to launch court actions to stop illicit practice. This authority is unbounded in its scope. The principle object mandates that PEO 'govern the profession of Engineering in order that the public interest be served and protected'. It is up to PEO to interpret what this means. The fundamentals of self-governance rely on the principle that the members of the profession are in the best position to judge who are competent practitioners of that profession. PEO must take the lead in advising our governments on what must be done with respect to governing and regulating the engineering profession in Ontario.

There are two methods to help enforce licensing authority – demand legislation and 'common law', the latter via the courts.

Demand Side Legislation

Demand Legislation is essentially legislation other than PEO's Act that proclaims a requirement to use a licensed individual to perform some action or do some work. Various ministries, in the course of their work, can ensure that the public interest is served and protected by specifying the use of individuals with the appropriate credentials. Such legislation does not automatically appear. Ministers, politicians and the general public must be informed of the need to use competent individuals. This is even more the case in a new discipline of engineering. In our context we need to call on PEO's Legislation Committee, aided by PEO's Government Liaison Committee, and perhaps by OSPE in their general role as engineering advocates. The focus of attention is to find existing legislation modifications and potentially new legislation that is required to enhance PEO's ability to regulate this new field of practice. An example of this is the

Railway Safety Act. All the Acts and regulations around the building code are primary examples that support Civil and Structural engineering rights to practice.

Common Law

'Common Law' rights to practice come about via the precedence that is set by a sufficiently high court of law. By setting precedence, the courts establish what specific works constitutes a practice in engineering.

For PEO, the Enforcement arm initiates court cases. Enforcement staff have been doing this effectively for a long time. However, staff must follow the rules as they are set. They are not in a position to drive the creation of new rules or to venture forth in a litigation strategy that is not a certainty. Litigation strategy is the role of the Enforcement Committee. It is empowered by PEO to investigate and determine strategies that will lead to society conformance to PEO's licensing authority. In its simplest form this can be a letter from PEO requesting conformance – for the NME discipline this means advising of the new practice of NME and the intention of PEO to properly regulate practice in this field.

More formally, the Enforcement Committee shall launch court actions in the event non-conformance has been found. This is most obvious in the case of an engineering failure where it has been determined that the offender (e.g. owner or contractor) appears to have not used the services of a licensed Professional Engineer.

By assuming an engineering role, the offender is guilty of practicing engineering without a licence. Lack of engineering oversight may have contributed to such cases as Walkerton, Elliot Lake, subway tunnel collapse, CNE display collapse, demolition collapse to name a few in recent (2013) memory.

If a licensed engineer was not used in doing an engineering work it is an action for the Enforcement Committee. If a Licensed engineer was involved, then PEO's discipline procedures take over.

Initially, a letter requesting compliance is sent. If we have a public willing to comply with the rules, we opt for cooperation to achieve compliance. In the big picture, PEO and engineering is part of our larger society which we are trying to build, make prosperous and keep safe. Where this fails the stronger litigation route must be initiated.

Through PEO's Enforcement Committee, the profession sets out a litigation strategy that is consistent with the practice of NME. This means taking action in a sufficiently high court to set such precedence.

In litigation, one begins with cases that are the most obvious as part of the practice of engineering. For example, the software used in elevators is a simple example. Elevator design is part of the practice of engineering. Software associated with the operation of elevators must also be done by a properly licensed individual. This is the argument that states, 'works that are already part of the practice of Engineering which has software added, must have that software also designed by a licensed engineer'. A generalization of this is any control system and/or automation software that causes an actuator on a process to move in a way that could affect worker or public safety.

It is up to the Enforcement Committee to examine NME practice to determine if there are current works that are already within the practice of Engineering. One example is the extension of Bio-Engineering in the design of medical equipment. The design and production of pharmaceuticals is another example closely associated with Chemical Engineering and Bio-Engineering.

To use the courts, a series of litigations is required that target works of the highest public interest impact. The profession has tended to shy away from such conflict. But without this activity the profession is not doing its duty. Governments have left it up to the engineering profession to 'serve and protect' the public with respect to the practice of engineering.

Engineers may have concerns about what happens if case is lost. However, here is the essential point:

If the courts fail to support a PEO action in an important way, we then have cause to go to our legislature and put the question to them, 'Does the law of the land want the profession to regulate a specific practice or not?' If yes, then the governments must enact Demand Side legislation to make it so. If not, then the governments must determine how the regulatory gap is to be filled given that a legitimate public interest is at stake. Either way, the public is served by ensuring our society has proper systems in place to serve and protect it.

Recommendations:

That PEO Council expand the Terms of Reference of the Legislation Committee to enable them to handle the following recommendations, (in the alternative, Council will need to determine who within PEO will provide Council with advice on how to proceed with actions requiring new Demand Side Legislation.)

That PEO Council direct the Legislation Committee to research the legislation within six months to determine what can be done to add demand legislation requirements to support the licensure and rights to practice in NME Target Domains listed above, and in any others that may from time to time come to be known, and that PEO Council consider, as policy, those recommendations from the Legislation Committee that are relevant to support these recommendations.

That Council direct the Legislation Committee to identify within six months government ministries at Federal and Provincial levels that can create mandatory reporting of incidents to the Provincial Engineering Licensing Authority, PEO, where Public Safety is at risk due to works related to the practice of Nanotechnology and Molecular Engineering; and, that PEO Council direct the Legislation Committee to pursue courses of action that create mandatory reporting requirements.

Target Domains (TD's)

It is helpful to identify Target Domains (TD's). As an analogy to explain what this means, consider the medical profession. Doctors learn a set of skills – can do surgery and prescribe medicines. They apply those skills to a TD known as the human body. Veterinarians have very similar skills but their TD's are animals other than the human. Hence, a TD is a key component to defining rights to practice. In the work of the Legislation Committee and the Enforcement Committee, TD's become necessary as legislation and court judgments are always specific not general. Identifying these upfront will help in establishing rights to practice. Target Domains are formally defined and described in The "Public Interest" of NME, provides for information on the public interest impacts of NME. Defining Target Domains must begin with an understanding such impacts. These are key to regulating the practice of Engineering in order that the public interest be served and protected as mandated in the PEO Act.

Section 2 highlights the issues of handling nanomaterials. It is clear that such materials can be hazardous to the environment and people's health. The Hazardous Products Act is one particular point of focus. In rolling out the NME practice, it is prudent that the handling and processing and disposal of nano materials be approved by a P.Eng. with the NME skill set. This is a reasonably broad TD in that there are several industries impacted including medical. It must be emphasized that NME is a horizontal discipline and thereby impacts many industries. Mining, semiconductor production, food production can all have nano processes with nano materials to be disposed.

In short, disposal of nanomaterials is a Target Domain for NME practitioners.

Closely linked to the disposal issue is handling of nano materials throughout the manufacturing process. Hence, design of new nano products and the design of the manufacturing process using nano techniques must be approved by a P.Eng. with NME skills.

This is the Target Domain of manufacturing nano products.

Sub-divisions of the above is the design of nano instrumentation, nano biotechnology and nano machines. It is useful to be specific here to assist in providing focus to PEO on exactly what it is that NME engineers do that impacts the public interest and thereby must be subject to proper licensing.

Specific Perspectives

It is well to keep the formal definition of engineering up front. The Act includes several activities (planning, designing, composing, evaluating, advising, reporting, directing or supervising) that are part of the work of engineers. For example, it is common for engineers to write reports and recommendations from their work. Such reports should be signed and sealed by the licensed engineer (a requirement that will soon become mandatory). This is an engineering work. Anyone changing that report is practicing engineering and will become responsible for the consequences of the change, including the original engineer's manager.

The same argument holds for the other activities associated with an engineering work. Only a licensed engineer is permitted to give an Engineering opinion. Giving such opinions in a court of law or in any important forum, is the practice of engineering and one must be licensed to do so.

Summary

Phase 2 must deal with these practice issues: practices that fall under this domain, and critically, the impacts on the public interest. Thus, this report helps PEO to serve and protect the public interest by ensuring that this new discipline is properly licensed with tangible rights to practice enshrined within our legal system.

Phase 2 focuses attention on rights to practice for this new discipline. This begins with setting out the scope of practice relative to the CBOK. PEO Council must then activate the Legislation Committee and the Enforcement Committee. To support this work, Council needs to direct the PSC to create a NME guideline.

Since the PEO was created in 1922, the profession has been slow in following through with extending rights to practice into TD's where engineering practice has grown. We are learning now as the pace of change continues to accelerate and we can see its impact. The profession must respond more quickly and, indeed, be proactive, in maintaining and extending exclusive rights to practice in new fields.

Engineering is unique in this respect since most of the major professions do not have expanding scopes of practice. Without rights to practice the Licence is meaningless and devolves to nothing more than a right to title. With established rights to practice, PEO has the means to protect the public interest with respect to the practice of Engineering, PEO's mandated purpose.

Recommendations:

In order that the public interest be served and protected by engineering practice the EDTF/NME subgroup recommends:

1. Whereas the fields of engineering practices tend to be broad in their world application and ever widening as new technologies are created, EDTF recommends that, PEO introduce the concept of Target Domains within its rubric[49] to assist in the regulation and governance of engineering practice.[50]

2. *In order that the public interest be served and protected by engineering practice the EDTF-NME group recommends the following initial Target Domains:*
    i. *That the design of medical equipment and the processes to make such products that use Nanotechnology is a domain for the practice of NME ;*
    ii. *The design and manufacturing of NME-based pharmaceuticals is a Target Domain of NME.*

[49] an established rule, tradition, or custom

[50] This concept allows the sub-partitioning of practices by referencing the target world objects of applying a specific engineering skill set, e.g. for CIE: Medical field, SCADA Smart Grid, Finance Sector, etc. It is important for PEO to assess which TD's have the greatest impact on the public interest and to use this assessment in prioritizing regulatory activities in Enforcement, Legislation, and Guidelines to match such priority.

5 Future Work

The Engineering profession is unique in that its set of practices expands with the growth of technology and science. In 1922 we began with 5 disciplines (Civil, Mechanical, Chemical, Electrical and Mining). Today there are over 30 disciplines and many more sub-variations. If anything, the rate of growth of new areas of practice is increasing at a geometric rate. There is also a tendency for some scientists to apply some new discovery to things that are useful for human consumption. Though this is done innocently of the law, when such steps are taken and a new public risk is introduced, the work has become Engineering by definition. Of course really new science like that in genomic manipulation, introduces unknown risks and really necessitates the discipline and judgment of the Engineer in applying the precautionary principle.

It is PEO's responsibility to govern the practice of engineering (in order that the public interest is served and protected). What we have now come to understand over the last 20 years beginning with the Software Engineering crisis, is that the profession is expanding as described above. Technology diffusion rates have gone from decades in the 1900's to years in the 2000's. We currently have more scientists and engineers alive today than ever in the history of human kind. So our rate of new discoveries and inventions in our current generation far exceeds our previous human history on this planet!

Standing Committee

The accelerating expansion of science and technology will result in new technology areas of practice arising on average every five years. PEO will need to gather intelligence on these and provide Council with the data it requires to make appropriate decisions as it strives to govern the Engineering profession in order that the public interest is served and protected.

The creation of this committee is one step in mitigating the run-away growth we are now recognizing. The committee is tasked to identify new disciplines as they come into existence and bring these to the attention of PEO Council for action. Without this committee PEO will not have the market and industry visibility it requires to fulfill its full mandate to govern all areas of engineering practice.

The proposal for this committee flows from work done by several Emerging Discipline Task Forces (Software, Bio-Engineering, and now, Nanotechnology & Molecular Engineering and Communications Infrastructure Engineering). Engineers Canada has seen this same need and has tasked CEQB (Canadian Engineering Qualifications Board) to take on a role much like the one we are proposing herein. It is the intention of this proposal to maintain an open dialogue with Engineers Canada on these matters so that we develop greater visibility of the growth in the profession.

The proposed Standing Committee is focused on the identification function. On identifying a significant new area of practice, the committee will bring a recommendation to Council to obtain the resources to create a Working Group of specialists in the new area to proceed with the details of Phase 1 and Phase 2 reports. Though there is likely some overlap in these reports, the general thrust is: Phase 1 defines the Core Body of Knowledge (CBOK) and Phase 2 deals with the rights to practice issues. In simple terms, (1) what is the new skill set? and (2) where will it be applied in the real world?

It is important that this committee do enough preliminary work to identify two key points:

1. what is expected to be different or novel about this skill set that is not found in another discipline of Engineering, and,
2. what are the significant public interest issues that are expected to arise in the practice of this new discipline?

In describing (1), it is legitimate to draw on 2 or more existing disciplines. The case is considered stronger when one or more Target Domains can be identified that link the new skill set to an emerging need in society. Public risk includes life and limb risks, and also risks to significant financial loss (Bre-X sets the precedent that a billion dollar loss that impacts many people is a public interest.) It is possible to argue psychological impact if this can be shown to be linked to suicide or significant loss of quality of life to individuals (e.g.: release of private information that inhibits an individual's ability to make a living).

Recommendation:

The EDTF supports and recommends to PEO Council that it create a standing committee to horizon watch for 'New Engineering Disciplines and Practices'.

Certification Process

This is equivalent to the processes used by medicine and law to recognise specialist practices and grants those who are qualified the right to a title/designation that they may use to market their services. For engineering, such titles will also serve government Ministries in creating Demand Legislation in these areas of practice by simplifying the task in precisely identifying individuals with specific skill sets.

Recommendation:

The EDTF recommends that PEO Council establish a new process to handle an enhanced certification. This is equivalent to the processes used by medicine and law to recognise specialist practices and grants those who are qualified the right to a title/designation that they may use to market their services.

Engineering Licence Credentials

We have also recognise that not only do engineers now require their technical knowledge but also require grounding in business know-how and in their ability to effectively communicate ideas to non engineers, particularly, to politicians and government ministers. Indeed, we believe that if existing disciplines were subjected to a rigorous assessment of their core body of knowledge and the extended body of knowledge required today, that they too will overflow the four year undergraduate degree time span.

Additionally, we recognise that Engineering is the only senior profession remaining that can be accessed directly from high school. All others have introduced bachelor degree entrance requirements to study their professions.

Furthermore, the US has declared that it will move to a Master's degree requirement for is PE licence by 2015.

Recommendation:

Whereas the EDTF recognizes that the full Core Body of Knowledge of these new disciplines is likely to exceed the time available to teach these subjects in the typical undergraduate curriculum, we recommend that Council direct the Licensing Process Task Force to urgently examine this matter and to recommend an appropriate course of action to Council within six months.

Glossary

NME: Nanotechnology and Molecular Engineering
Nanoscale
size range from approximately 1 nm to 100 nm

NOTE 1 Properties that are not extrapolations from a larger size will typically, but not exclusively, be exhibited in this size range. For such properties the size limits are considered approximate.
NOTE 2 The lower limit in this definition (approximately 1 nm) is introduced to avoid single and small groups of atoms from being designated as nanoobjects or elements of nanostructures, which might be implied by the absence of a lower limit.

[ISO/TS 80004-1:2010, definition 2.1]
nanotechnology
application of scientific knowledge to manipulate and control matter in the nanoscale in order to make use of size- and structure-dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials

NOTE Manipulation and control includes material synthesis.

[ISO/TS 80004-1:2010, definition 2.3]
Nanoscience
study, discovery and understanding of matter in the nanoscale, where size- and structure-dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials, can emerge
nanoobject
material with one, two or three external dimensions in the nanoscale

NOTE Generic term for all discrete nanoscale objects.

[ISO/TS 80004-1:2010, definition 2.2]

Nanomaterial
material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale

NOTE 1 This generic term is inclusive of nanoobject and nanostructured material.
NOTE 2 See also engineered nanomaterial, manufactured nanomaterial and incidental nanomaterial

[ISO/TS 80004-1:2010, definition 2.4]
engineered nanomaterial
nanomaterial designed for a specific purpose or function
[ISO/TS 80004-1:2010, definition 2.1]
nanoenabled
function or performance made possible by nanotechnology

[ISO/TS 80004-1:2010, proposed new term for ISO amendment December 2012]
Nanotoxicology

application of toxicology to the study of nanomaterials

[ISO/TS 80004-5:2011, definition 3.4]

Nanobiotechnology
application of nanoscience or nanotechnology to biology or biotechnology
NOTE This includes the application of nanotechnology to human health and veterinary science.
[ISO/TS 80004-1:2010, definition 2.2]
nanoparticle
nanoobject with all three external dimensions in the nanoscale

NOTE If the lengths of the longest to the shortest axes of the nanoobject differ significantly (typically by more than three times), the terms nanofibre or nanoplate are intended to be used instead of the term nanoparticle.
[ISO/TS 27687:2008, definition 4.1]
Nanofibre
nanoobject with two similar external dimensions in the nanoscale and the third dimension significantly larger

NOTE 1 A nanofibre can be flexible or rigid.
NOTE 2 The two similar external dimensions are considered to differ in size by less than three times and the significantly larger external dimension is considered to differ from the other two by more than three times.
NOTE 3 The largest external dimension is not necessarily in the nanoscale.

[ISO/TS 27687:2008, definition 4.3]

nanoprocesses and nanoprocessing
Equipment and operations used to make nanomaterials on a laboratory or industrial scale, and processes (and operations) using nanomaterials for the manufacture of other products, e.g. as catalysts or constituents,"

nanotube
hollow nanofibre
[ISO/TS 27687:2008, definition 4.4]
carbon nanotube
nanotube composed of carbon

NOTE Carbon nanotubes usually consist of curved graphene layers, including single-wall carbon nanotubes and multiwall carbon nanotubes.
[ISO/TS 80004-3:2010, definition 4.3]

Bibliography
[1] ISO/TS 27687:2008, *Nanotechnologies — Terminology and definitions for nanoobjects — Nanoparticle, nanofibre and nanoplate*

[2] ISO/TS 80004-1:2010, *Nanotechnologies — Vocabulary — Part 1: Core terms*

[3] ISO/TS 80004-3:2010, *Nanotechnologies — Vocabulary — Part 3: Carbon nanoobjects*

[4] ISO/TS 80004-5:2011, *Nanotechnologies — Vocabulary — Part 5: Nano/bio interface*

Appendix A – NME Stakeholders consulted

The following organizations have been contacted by the EDTF NME group and engaged in dialogue regarding NME:

1. Engineers Canada (CEAB, CEQB, CAE, Constituent Members, NCDEAS)
2. Ontario Ministry of Environment
3. Ontario Ministry of Research & Innovation
4. Health Canada
5. Agriculture and Agri-Food Canada
6. Fisheries and Oceans Canada
7. Environment Canada
8. Industry Canada
9. PEO Committees – Academic Requirements, Experience Requirements, Professional Standards, Enforcement, Complaints, Discipline
10. BioTalent Canada
11. Canadian Council of Consumers (CCC)
12. Canadian Standards Association (CSA)
13. ISO TC229 Canadian Advisory Committee
14. NANO Ontario
15. NANO Quebec
16. NANO Alberta
17. Ontario Institute for Cancer Research
18. Council of Ontario Deans of Engineering (CODE)
19. BIOTECanada
20. Canadian Pharmaceutical Association
21. Ontario Society of Professional Engineers (OSPE)
22. Ontario Association of Certified Engineering Technologists and Technicians (OACETT)
23. Consulting Engineers Ontario
24. IEEE Nano
25. Canadian Association of Physicists
26. Canadian Association of Environmental Biologists – Ontario
27. Association of the Chemical Profession of Ontario (ACPO)
28. Canadian Society for Chemical Engineering
29. Canadian College of Microbiologists
30. Chemical Institute of Canada
31. Canadian Society of Microbiologists

Appendix B – List of Ontario Industries/companies using NME

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
1	Bayer Inc. Etobicoke, ON	Primary Industry: Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	(416) 248-0771 Number of Employees: 175 Total Sales: (CDN) $25M to $49.9M http://www.bayer.ca (Information dates from 2010-02-04)
2	L2B Environmental Systems Inc. Barrie, ON	Primary Industry: Measuring and Medical and Controlling Devices (Manufacture, Processor, Producer)	Not in Directory	(705)733-3493 Number of Employees: Not indicated Total Sales: (CDN) Not indicated http://www.L2Binc.com (Information dates from 2010-06-21) William Morrow, VP Research/Development/ Engineering (Not licensed P.Eng.) Organization offers Engineering Services – not listed in CofA Directory
3	Motorola Canada Limited Markham, ON	Primary Industry: Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing (Manufacture, Processor, Producer)	C of A Holder	(905) 948-5200 Number of Employeess: 700 Total Sales: (CDN) $50,000,000 + http://www.motorola.ca (Information dates from 2010-04-06)
4	PCI Health Trade (Alternate name BiopharmCanada) North York, ON	Primary Industry: Wholesale Trade Agents and Brokers (Importer Medical Device-Industrial Chemicals-Food Additives)	Not in Directory	(416) 855-9644 Number of Employees: 5 Total Sales (CDN) $1 to $99,999 http://WWW.PCIHEALTHTRADE.COM
6	Cytodiagnostics Inc. Burlington, ON	Primary Industry: Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	(866) 344-3954 Number of Employees: N/A Total Sales: N/A http://www.cytodiagnostics.com (Information Dates from: 2010-07-28
7	GlaxoSmithKline Inc. MISSISSAUGA, Ontario	Primary Industry: Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Telephone: (905) 819-3000 Fax: (905) 819-3099 Number of employees: N/A Total Sales: N/A Website URL: http://www.gsk.ca Jeffrey Launay Title: Policy Analyst Telephone: (905) 819-3003 Email: jeffrey.g.launay@gsk.com
8	PharmaCosmetic INTERNATIONAL (PCI) HEALTH & BEAUTY TRADING	Primary Industry: Wholesale Trade Agents and Brokers	Not in Directory	Telephone: (416) 855-9644 Fax: (866) 252-7199 Number of Employees:5 Total Sales CDN $1 to $99,999

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
	LTD. NORTH YORK, Ontario			Email: pci@PCIHEALTHTRADE.COM Website URL: http://WWW.PCIHEALTHTRADE.COM Sonia Abachi: President Telephone: (416) 855-9644 Email: pci@pcihealthtrade.com
9	Realform Technologies ETOBICOKE, Ontario	Primary Industry: Urethane and Other Foam Product (except Polystyrene) Manufacturing	Not in Directory	Paolo Marini Title: President Telephone: (416) 367-3626 Fax: (416) 367-3623 Number of employees: 11 Total sales: CDN $1,000,000 to $4,999,999 Email: paolo_marini@realformtech.com Web: http://www.realformtech.com/CONTACT.html
10	Altech Technology Systems Inc. EAST YORK, Ontario	Primary Industry: Commercial and Service Industry Machinery Manufacturing	Not in Directory	ALEX KEEN Title: PRESIDENT Telephone: (416) 467-5555 Fax: (416) 467-9824 Number of employees:16 Total sales:CDN $100,000 to $499,999 Email: akeen@altech-group.com Web: http://www.altech-group.com/ats_aboutus.htm
11	ATS Automation Tooling Systems Inc. CAMBRIDGE, Ontario	Primary Industry: Measuring, Medical and Controlling Devices Manufacturing	Not in Directory	Paul Patterson Title: Manager Area of Responsibility: Domestic Sales & Marketing Telephone: (519) 653-6500 Fax: (519) 653-6533 Number of employees: 3,400 Total Sales: CDN $50,000,000+ Email: ppatterson@atsautomation.com Web: http://www.atsautomation.com/
12	CG2 NanoCoatings Inc. STITTSVILLE, Ontario	Primary Industry: Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Amlan Gupta Title: President Area of Responsibility: Management Executive Telephone: (613) 435-7747 Fax: (413) 638-3933 Number of Employees: N/A Total Sales: N/A Email: agupta@cg2nanocoatings.com Web: http://www.cg2nanocoatings.com/
13	Enervac Corporation CAMBRIDGE, Ontario	Primary Industry: Commercial and Service Industry Machinery Manufacturing	Not in Directory	Anthony Guglielmi Title: President Area of Responsibility: Management Executive Finance/Accounting Manufacturing/Production/Operations Telephone: (519) 651-1034 Fax: (519) 651-1038 Number of Employees:40

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
14				Total Sales CDN: $10,000,000 to $24,999,999 Email: anthonyg@enervac.com Web:
14	GE Water & Process Technologies OAKVILLE, Ontario	Primary Industry: Commercial and Service Industry Machinery Manufacturing	Not in Directory	Pete Bierden Title: Engineer Area of Responsibility: Management Executive Telephone: (905) 465-3030 Fax: (905) 465-3050 Number of Employees: 1,400 Total Sales CDN: $50,000,000+ Web: http://www.gewater.com/index.jsp
15	GPEKS Clean Energy Development OTTAWA, Ontario	Primary Industry: Other Scientific and Technical Consulting Services	Not in Directory	Frederic Pouyot Title: President & CEO/Prés. Directeur Général Telephone: (819) 775-2760 Number of Employees: N/A Total Sales:N/A Email: fpouyot@gpeks.com Web: http://info.cleanenergyeducation.net/
16	Integrity Testing Laboratory Inc. MARKHAM, Ontario	Primary Industry: Testing Laboratories	Not in Directory	Jacob Kleiman Title: President Area of Responsibility: Management Executive Telephone: (905) 415-2207 Fax: (905) 415-3633 Number of employees: 16 Total Sales CDN: $1,000,000 to $4,999,999 Email: jkleiman@itlinc.com Web: http://www.itlinc.com/
17	Intellectual Alliance Inc. CONCORD, Ontario	Manufacturer/ Processor/ Producer - Carbon nano structures	Not in Directory	Bob Young, Title: Vice President Area of Responsibility: Domestic Sales and Marketing Telephone: (905) 482-9133 Fax: (905) 482-9134 Number of employees:7 Total Sales CDN:$500,000 to $999,999 Email: intcan@idirect.com Web: http://www.dlc-coating.ca
18	Intelligent MEMS Design OTTAWA, Ontario	Wholesaler/ Distributor Medical devices, wireless tire monitoring system, digital tire pressure gauges, sensors	Not in Directory	Jay Esfandyari Title: Chief Executive Officer Telephone: (613) 596-9686 Fax: (419) 8331-3422 Number of employees:N/A Total Sales CDN:N/A Email: info@imemsdesign.com Web: http://www.imemsdesign.com/
19	Iridian Spectral Technologies	Semiconductor and Other Electronic	Not in Directory	George Laframboise Title: President

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
	OTTAWA, Ontario	Component		Area of Responsibiity: Management Executive Telephone: (613) 741-9780 Fax: (613) 741-9986 Number of employees:50 Total Sales CDN: N/A Email: George.laframboise@iridian.ca Web: http://www.iridian.ca/
20	Maratek Environmental Inc.l BOLTON, Ontario	Environmental Consulting Services – Plastic film recycling and disposal	Not in Directory	Andrew Maxwell Title: General Manager Telephone: (905) 857-2738 Fax: (905) 857-2764 Number of employees: 35 Total Sales: $500,000 to $999,999 Web: http://maratek.com/home/
21	NANOWave Technologies Inc. ETOBICOKE, Ontario	Semiconductor and Other Electronic Component Manufacturing	Not in Directory	Justin Miller Title: President Area of Responsibility: Management Executive Telephone: (416) 252-5602 Fax: (416) 252-7077 Number of employees: 125 Total Sales: $10,000,000 to $24,999,999 Email: jmiller@nanowavetech.com Web: http://www.nanowavetech.com/
22	PackagingOne Corporation WATERLOO, Ontario	Engineering Services	Not in Directory	Ric Asselstine Title: CEO Telephone: (519) 884-1117 Fax: (519) 884-8452 Number of employees: N/A Total Sales: N/A Email: ric@packagingone.com No current website found.
23	Passat Ltd./APR Technologies NORTH YORK, Ontario	Measuring, Medical and Controlling Devices Manufacturing	Not in Directory	Guerman Pasmanik Title: President Area of Responsibility: Management Executive Telephone: (416) 661-0996 Fax: (416) 661-0996 Number of employees: 11 Total Sales: $500,000 to $999,999 Email: info@PassatLtd.com Web: http://www.passatltd.com/
24	Precision Dynamics BURLINGTON, Ontario	Measuring, Medical and Controlling Devices	Not in Directory	Michael Failes Title: Data Provider Telephone: (905) 332-7192 Fax: (905) 332-1808 Number of Employees: N/A Total Sales: N/A Email: sales@predynamics.com Web: http://www.pdcorp.com/

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
25	V+I Group Inc. NEPEAN, Ontario	Research and Development in the Physical Engineering and Life Sciences	Not in Directory	Jerome LeCorvec Title: President Telephone: (613) 723-1001 Fax: (613) 723-0925 Number of employees: N/A Total Sales: N/A Email: Jerome.lecorvec@v-igroup.com Web: http://www.v-igroup.com/
26	APC Filtration Inc. ANCASTER, Ontario	All Other General Purpose Machinery Manufacturing	Not in Directory	Russell Kelly Title: President Telephone: (905) 648-5500 Fax: (905) 648-5800 Number of Employees: 23 Total Sales: $5,000,000 to $9,999,999 Email: rkelly@apcfilters.com Web: http://www.apcfilters.com/index.php
27	Canadian Instrumentation & Research Ltd. OAKVILLE, Ontario	Semiconductor and Other Electronic Component Manufacturing	Not in Directory	Michael Failes (see Precision Dynamics above) Title: President Area of Responsibility: Management Executive Telephone: (905) 332-1353 Fax: (905) 332-1808 Number of employees: 15 Total Sales: $1,000,000 to $4,999,999 Web: http://www.cirl.com/
28	Cytodiagnostics Inc. BURLINGTON, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Scott Kordyban Title: Chief Executive Officer Telephone: (289) 291-3362 Fax: (289) 288-0122 Number of Employees: N/A Total Sales: N/A Email: skordyban@cytodiagnostics.com Web: http://www.cytodiagnostics.com/
29	Design 1st Inc. OTTAWA, Ontario	Engineering Services	Not in Directory	Kevin Bailey Title: President Area of Responsibility: Research/ Development/ Engineering Telephone: (613) 235-1004 Number of Employees:12 Total Sales: $1,000,000 to $4,999,999 Email: kjbailey@design1st.com Web: http://www.design1st.com/
30	Integran Technologies Inc. ETOBICOKE, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Francisco Gonzalez Title: Vice President Area of responsibility: Research / Development / Engineering Telephone: (416) 675-6266 Fax: (416) 675-1666 Number of Employees: 47 Total Sales: N/A Email: Gonzalez@integran.com

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
				Web: http://www.integran.com/index.html
31	Johnsen Ultravac Inc. BURLINGTON, Ontario	Commercial and Service Industry Machinery Manufacturing	Not in Directory	Mike Nagy Title: Engineering Manager Area of Responsibility: Research/ Development/ Engineering Telephone: (905) 335-7022 Fax: (905) 335-4201 Number of Employees: 15 Total Sales: $1,000,000 to $4,999,999 Email: juvinfo@ultrahivac.com Web: http://www.ultrahivac.com/
32	L-3 Wescam NORTH YORK, Ontario	Commercial and Service Industry Machinery Manufacturing	Not in Directory	Adrian Burke Title: Sale and Operations Manager Telephone: (416) 445-1870 Fax: (416) 445-7977 Number of Employees: 50 Total Sales: $5,000,000 to $9,999,999 Email: Adrian.burke@L-3com.com Web: http://www.wescam.com/
33	Magellan Aerospace Corporation MISSISSAUGA, Ontario	Aerospace Product and Parts Manufacturing	Not in Directory	James S. Butyniec Title: President Area of Responsibility: Management Executive Telephone: (905) 677-1889 Fax: (905) 677-5658 Number of Employees: 3,000 Total Sales: $50,000,000+ Email: jim.butyniec@magellan.aero Web: http://www.magellanaerospace.com/
34	Tundra Semiconductor Corporation KANATA, Ontario	Semiconductor and Other Electronic Component Manufacturing	Not in Directory	Daniel Hoste Title: Chief Executive Officer Telephone: (613) 592-0714 Fax: (613) 592-1320 Number of Employees: ? Total Sales: ? Email: daniel.hoste@tundra.com Web: http://www.idt.com/ Tundra Semiconductor was acquired by IDT
35	3M Canada Company LONDON, Ontario	All Other Miscellaneous Chemical Product Manufacturing	Not in Directory	Brain Young Title: President Telephone: (519) 451-2500 Fax: (519) 452-6029 Number of employees: 1202 Total Sales: N/A Web: http://www.3m.com/intl/ca/
36	ALFT Inc. KANATA, Ontario	Measuring, Medical and Controlling Devices Manufacturing	Not in Directory	Robert Dotten Title: General Manager Telephone: (613) 287-0470 Number of Employees: N/A Total Sales:N/A Email: rob.dotten@alft.com

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
				Web: http://www.alft.com/default.asp
37	ARISE Technologies Corporation WATERLOO, Ontario	All Other Miscellaneous Manufacturing	C of A Holder	Frank Ruffolo Title: Manager Area of Responsibility: Domestic Sales & Marketing Telephone: (519) 274-7383 Fax: (519) 725-8907 Number of Employees: N/A Total Sales: N/A Email: corporatesales@arisetech.com Web: http://www.arisetech.com/
38	Axela Biosensors TORONTO, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Paul Smith Title: VP Sales and Business Planning Research Telephone: (416) 260-9050 Fax: (416) 260-9255 Number of Employees: 28 Total Sales: $200,000 to $499,999 Email: dotlabinfo@axelbiosensors.com Web: http://www.axelabiosensors.com/
39	Buehler Canada WHITBY, Ontario	Professional Machinery, Equipment and Supplies Wholesaler-Distributors	Not in Directory	Rick Blackwell Title: General Manager Area of Responsibility: Domestic Sales & Marketing Telephone: (905) 201-4686 Number of Employees: 10 Total Sales: N/A Email: info@buehler.ca Web: http://www.buehler.ca/default.htm
40	Centre for Earth and Environmental Technology NORTH YORK, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Richard D. Worsfold Title: Director Telephone: (416) 665-5473 Fax: (416) 665-2032 Number of Employees: N/A Total Sales: N/A Email: worsfold@admin.crestech.ca Web: http://www.oce-ontario.org/Pages/COEEarth.aspx?COE=EA
41	COM DEV International Limited CAMBRIDGE, Ontario	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Not in Directory	John Keating Title: Chief Executive Officer Area of Responsibility: Management Executive Telephone: (519) 622-2300 Fax: (519) 622-1691 Number of Employees: 750 Total Sales: $50,000,000 + Email: john.keating@comdev.ca Web: http://www.comdev.ca/
42	DALSA Corporation WATERLOO, Ontario	Semiconductor and Other Electronic Component	Not in Directory	Savvas Chamberlain Title: Chief Executive Officer Area of Responsibility: Management

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
		Manufacturing		Executive Telephone: (519) 886-6000 Fax: (519)886-8023 Number of Employees: 1,000 Total Sales:$50,000,000 + Web: http://www.dalsa.com/
43	GCM Tech MARKHAM, Ontario	Engineering services Measuring, Medical and Controlling Devices Manufacturing	CofA Holder	Shaun Ghafari Title: Chief Executive Officer Area of Responsibility: Management Executive Telephone: (905) 477-5426 Number of Employees:N/A Total Sales: N/A Email: shaun.ghafari@gcmtech.ca Web: http://www.gcmtech.ca/
44	Huron Technologies International Inc. WATERLOO Ontario	Commercial and Service Industry Machinery Manufacturing	Not in Directory	Arthur Dixon Title: Chief Executive Officer Area of Responsibility: Management Executive Telephone: (519) 886-9013 Number of Employees: 6 Total Sales: $500,000 to $999, 999 Email: aedixon@confocal.com Web: http://huron-technologies.com/
45	Skynanotech OTTAWA, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Igor Ratchkov Title: Chief Executive Officer Area of Responsibility: Customer Service Government Relations Management Executive Manufacturing/ Production/Operations Research/Development/Engineering Number of Employees: 10 Total Sales: N/A Telephone: (613) 692-9779 Web: http://www.skynanotech.com/
46	AM&M Advanced Machine and Materials Inc. KANATA, Ontario	All Other Basic Inorganic Chemical Manufacturing	Not in Directory	Julia C Title: President Area of Responsibility: Management Executive Telephone: (613) 482-1155 Fax: (613) 822-5113 Number of Employees: N/A Total Sales: N/A Email: juliac@am-m.com Web: http://www.am-m.com/
47	Hydrogenics Corporation MISSISSAUGA, Ontario	All Other Electrical Equipment and Component Manufacturing	Not in Directory	Jonathan Dogterom Title: Director Area of Responsibility: Export Sales & Marketing Telephone: (905) 361-3660 Email: jdogterom@hydrogenics.com Web: http://www.hydrogenics.com/

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
48	Frid Enterprises Inc. PLANTAGENET, Ontario	Heating Equipment and Commercial Refrigeration Equipment Manufacturing	Not in Directory	Randy Frid Title: President Telephone: (613) 859-3743 Number of Employees: N/A Total Sales: N/A Email: randyfrid@hotmail.com Web: no website
49	NRC, Institute for Microstructural Sciences TTAWA Ontario	Primary Production of Alumina and Aluminum	Not in Directory	Thomas Jackman Title: Director Area of Responsibility: Management Executive Telephone: (613) 993-6711 Fax: (613) 957-8734 Number of Employees: N/A Total Sales: N/A Web: http://www.nrc-cnrc.gc.ca/eng/ibp/ims.html
50	Rio Tinto Alcan Inc. – Specialty Aluminas BROCKVILLE, Ontario		Not in Directory	Bruno Morin Telephone: Manager Area of Responsibility: Export Sales and Mareketing Telephone: (613) 851-5092 Fax: (613) 342-6943 Number of Employees:N/A Total Sales:N/S Email: Bruno.morin@riotinto.com Web: http://www.riotintoalcan.com/
51	Unimin Canada Ltd. ETOBICOKE, Ontario	All Other Non-Metallic Mineral Mining and Quarrying	Not in Directory	William Zielinski Title: General Sales Manager Telephone: (416) 626-1500 Fax: (416) 626-1855 Number of Employees: 214 Total Sales: N/A Email: inquiries@unimin.com Web: http://www.unimin.com/
52	Lauritech Inc. SCARBOROUGH, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Steven Lauriault Title: President Telephone: (416) 283-4066 Fax: (416) 283-4066 Number of employees: 1 Total Sales: $1 to $99,999 Email: steve@lauritech.com Web: no website
53	Tele-Education Canada Division, EmptInfology Research Centre SCARBOROUGH, Ontario	Other Scientific and Technical Consulting Service	Not in Directory	Pei Kan Title: Chairman Area of Responsibility: Research / Development/ Engineering Telephone: (416) 417-0361 Number of Employees: Total Sales: Email: DrPxKan@gmail.com Web: no website

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
54	Bereskin & Parr Intellectual Property Law TORONTO, Ontario	Offices of Lawyers	Not in Directory	Philip Mendes da Costa Title: Managing Partner Telephone: (416) 364-7311 Fax: (416) 361-1398 Number of employees: 250 Total Sales: N/A Email: pmdcosta@bereskinparr.com Web: http://www.bereskinparr.com/
55	CMC Microsystems KINGSTON, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Ian McWalter Title: President and CEO Area of Responsibility: Management Executive Telephone: (613) 530-4653 Fax: (613) 548-8104 Number of Employees: 50 Total Sales: N/A Web: http://www.cmc.ca/en.aspx
56	Integran Technologies Inc. ETOBICOKE, Ontario	Research and Development in the Physical, Engineering and Life Sciences	Not in Directory	Francisco Gonzalez Title: Vice President Area of Responsibility: Research/ Development/Engineering Telephone: (416) 675-6266 Fax: (416) 675-1666 Number of Employees 47 Total Sales: N/A Email: Gonzalez@integran.com Web: http://www.integran.com/
57	MuAnalysis Inc. OTTAWA, Ontario	Testing Laboratories	Not in Directory	Martine Simard-Normandin Title: President and CEO Telephone: (613) 721-4664 Fax: (613) 721-4682 Number of Employees: N/A Total Sales: N/A Email: martine@muanalysis.com Web: http://www.muanalysis.com/
58	Canada Analytical & Process Technologies NEPEAN, Ontario	Professional Machinery, Equipment and Supplies Wholesaler-Distributors	Not in Directory	Bill Shurben Title: Sales Manager Telephone: (613) 226-1115 Fax: (613) 226-5429 Number of Employees: N/A Total Sales: N/A Email: bshurben@captcanada.com Web: http://www.captcanada.com/
59	CCR Process Products KANATA, Ontario	Industrial Machinery, Equipment and Supplies Sholesalers-Distributors	Not in Directory	Claude Martel Title: Service Manager Telephone: (613) 723- 3386 Fax: (613) 723-3386 Number of Employees: N/A Total Sales: N/A Email claude@ccrprocessproducts.com Web: http://www.ccrprocessproducts.com/

Organizations in Ontario involved in NanoTECH Industry/R&D				
	Organization	Primary Industry	CofA Holder	Details
60	OCI Vacuum Microengineering Inc. LONDON, Ontario	Measuring, Medical and Controlling Devices Manufacturing	Not in Directory	Jozef G. Ociepa Title: President Area of Responsibility: Management Executive Telephone: (519) 457-0878 Fax: (519) 457-0837 Number of Employees: 6 Total Sales: $500,000 to $999,999 Email: jociepa@ocivm.com Web: http://www.ocivm.com/
61	ALTAIR Engineering Canada, Ltd. NORTH YORK, Ontario	Computer Systems Design and Related Services	C of A Holder	Robert Little Title: President Area of Responsibility: Research/ Development/Engineering Telephone: 416-447-6463 Number of Employees: N/A Total Sales: N/A Email: rbl@altair.com Web: http://www.altair.com/Default.aspx
All the above organizations are listed at: http://www.ic.gc.ca/eic/site/aimb-dgami.nsf/eng/03458.html				

Other Research Organizations:

Organization	Description
NanoOntario	Nano Ontario is a not-for-profit organization that represents the interests of academic, government, industrial, and finance community members in the development of nanotechnologies in Ontario. Nano Ontario's members work together to raise the profile, increase the research, build the investment and drive economic returns from nanotechnology in the province and across Canada. Vision: Nano Ontario is a trusted source of information for all nanoscience and nanotechnology activity in Ontario. Nano Ontario can advise government organizations on economic opportunity, policy, standards & regulations that nanotechnology can offer, to enable Ontario to benefit and capitalize from its nano research, development, and commercial capacity. Objectives: Maps Ontario's capacity in nanotechnology research, development, and commercialization. Serve as the main point of contact for Ontario's community of practice in nanoscience & nanotechnology. Builds and facilitates new connections between nanotechnology groups in universities, government organizations and industries within Ontario, across Canada, and internationally. Coordinates public outreach activities to advocate the societal benefits enabled by nanoscience and nanotechnology.
http://www.nanotechproject.org/ Project on Emerging Nanotechnologies Woodrow Wilson International Center for Scholars Ronald Reagan Building and International Trade Center One Woodrow Wilson Plaza 1300 Pennsylvania Ave., NW, Washington, DC 20004-3027 Phone: (202) 691-4398 Fax: (202) 691-4001 E-Mail: nano@wilsoncenter.org	Mission The Project on Emerging Nanotechnologies was established in April 2005 as a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts. The Project is dedicated to helping ensure that as nanotechnologies advance, possible risks are minimized, public and consumer engagement remains strong, and the potential benefits of these new technologies are realized. Nanotechnologies are hailed by many as the next industrial revolution. They promise to change everything from the cars we drive to the clothes we wear, from the medical treatments our doctors can offer to our energy sources and workplaces. Although focused on the very small, nanotechnologies offer tremendous potential benefits. From new cancer therapies to pollution-eating compounds, from more durable consumer products to detectors for biohazards like anthrax, from novel foods to more efficient solar cells, nanotechnologies are changing the way people think about the future. The Project on Emerging Nanotechnologies collaborates with researchers, government, industry, NGOs, policymakers, and others to look long term, to identify gaps in knowledge and regulatory processes, and to develop strategies for closing them. The Project will provide independent, objective knowledge and analysis that can inform critical decisions affecting the development and commercialization of nanotechnologies. Our goal is to inform the debate and to create an active public and policy dialogue. It is not an advocate either for, or against, particular nanotechnologies. We seek to ensure that as these technologies are developed, potential human health and environmental risks are anticipated, properly understood, and effectively managed. All research results, reports, and the outcomes of our meetings and programs are made widely available through publications and over the web. We include a wide variety of stakeholders, both domestically and internationally, in our work. We also are committed to engaging a new generation of young people interested in working at the interface of public policy and nanoscience and nanoengineering. We run an active program with university researchers, educators, and students to further that objective.

Organization	Description
Western Institute for Nanomaterials Science Contact information is the Department of Science at UWO	University of Western Ontario WINS is a Faculty of Science initiative, and will have active participants from the Departments of Physics & Astronomy, Chemistry, Earth Sciences, Biology, Applied Mathematics, and Computer Science. It is anticipated that the membership will be expanded at a later time to include individuals from the Faculty of Engineering and the Faculty of Medicine & Dentistry. Materials and Biomaterials has been designated one of the core theme area in the Academic Plan of the Faculty of Science. The establishment of WINS can therefore be viewed as a natural evolution of the Academic Plan in that the mandate of WINS is to integrate and expand UWO Science's already distinguished efforts in the interdisciplinary fields of materials at the nanoscale. WINS has three main objectives: 1.) To provide a cohesive presence and collective vision for the departments, laboratories and facilities that presently work on nanomaterials. 2.) To develop a graduate program in Materials and Biomaterials sciences. This will be strongly integrated with the undergraduate programs in the same area recently introduced by the Faculty of Science 3.) To serve as an organization where UWO researchers in materials science will be able to meet, interact and collaborate effectively, as a communication link to the outside world.
London Centre for Nanotechnology London Centre for Nanotechnology 17-19 Gordon Street London WC1H 0AH tel: +44 (0)20 7679 0604 fax: +44 (0)20 7679 0595 email: lcn-administrator@ucl.ac.uk	The London Centre for Nanotechnology is a UK-based multidisciplinary enterprise operating at the forefront of science and technology. Our purpose is to solve global problems in information processing, healthcare, energy and environment through the application of nanoscience and nanotechnology. Founded in 2003, the LCN is a joint venture between University College London and Imperial College London and based at the Bloomsbury and South Kensington sites. The LCN occupies a purpose-built eight storey facility in Gordon Street, Bloomsbury (opened in 2006) as well as extensive facilities within different departments at South Kensington. The Centre's experimental research is supported by leading edge modelling, visualisation and theory through its access to state-of-the-art clean-room, characterisation, fabrication, manipulation and design laboratories. The Centre has a unique operating model that accesses and focusses the combined skills of both universities across several key departments; Chemistry, Physics, Materials, Medicine, Electrical and Electronic Engineering, Mechanical Engineering, Chemical Engineering, Biochemical Engineering and Earth Sciences. The LCN also has strong relationships with the broader nanotechnology and commercial communities and is involved in many major collaborations. As the world's only such facility located in the heart of a metropolis, the Centre has superb access to corporate, investment and industrial partners. It is at the forefront of nanotechnology training and enjoys a strong media presence around educating the public and bringing transparency to this far-reaching and emerging science.
Centre of Catalysis Research and Innovation	Broken Link
Centre for Advanced Nanotechnology **DIRECTOR** Professor Harry E. Ruda Tel: 416-978-4556 **ruda@ecf.utoronto.ca** **Administrative Assistant and Business Officer** Millie Morris Tel: 416-978-4556 **ecanmpm@ecf.utoronto.ca**	What is Nanotechnology? An emerging, multidisciplinary field for designing, fabricating and applying nanometre-scale materials, structures and devices. Nanoscale: for example, a single human hair is about 100,000 nanometres in diameter. One of the dominant technologies of the 21st century. Technology relying on novel phenomena arising in nanometre-sized clusters of atoms - nanostructures - often termed 'functional nanostructures'. Harnessing such structures is expected to lay the foundation for new products and processes that will significantly improve our standard of living. What is CAN? **The Centre for Advanced Nanotechnology:** Canada's *first* centre for nanotechnology research, formed in September 1997 under the name The Energenius Centre for Advanced Nanotechnology (ECAN) as a result of a generous donation from Energenius Inc., a

Organization	Description
	Canadian company dedicated to advancing nanotechnology research. As CAN's founding member and supporter of the Energenius Chair in Advanced Nanotechnology held by Professor Harry Ruda, Energenius entered into a strong partnership with CAN in promoting the commercialization and spin-off of nanotechnology advances to CAN and to the global market. Strong industrial support, a team of world-leading research scientists and state-of-the-art tools place CAN at the forefront for developing the key enabling technologies, nanoelectronic and nanophotonic applications, in which nanotechnology will make its first major impact - information technologies, advanced manufacturing and advanced materials and processes. What is CAN's mission? To provide visionary leadership in creating a solid, dynamic, multidisciplinary research and development infrastructure for Canada. To establish critical mass of principal investigators and facilities to enable us to perform internationally competitive research. To promote economic development in Ontario and in Canada, and to contribute to the training of highly-qualified personnel for careers in nanotechnology.
Centre for Research in Micro- and NanoSystems	Broken link
http://www.sse.gov.on.ca/medt/investinontario/en/Pages/OS_nanotechnology.aspx Ontario Government Sector website	On the frontline of the new industrial revolution Nanotechnology holds the promise of transforming virtually every high-tech industry from advanced manufacturing to life sciences to information technology. Unlocking and harnessing its potential requires four essential elements: Great science. World-class research infrastructure. Skilled workers. And supportive government. Ontario has all of that - in a positive investment climate. If you're serious about capitalizing on nanotechnology, there's no better place to be than Ontario. Take the new Quantum-Nano Centre at the University of Waterloo for example. In June 2008, the University of Waterloo broke ground on a $160 million research centre that aims to propel the university and the province to the forefront of the science of the very small. When it opens in late 2010 or early 2011, the Mike and Ophelia Lazaridis Quantum-Nano Centre (QNC) will be the only facility of its kind in the world - and the potential synergies produced by nano and quantum researchers working side by side promises to be truly groundbreaking. University of Waterloo Chancellor Mike Lazaridis says, "In addition to housing state-of-the-art research labs, this new building will provide a unique environment that will bring together the brightest minds in basic and applied research to explore and advance quantum computing and nanotechnology." The facility, which is receiving close to $70 million in support from the government of Ontario, includes the most advanced fabrication facilities for quantum and nano devices, an advanced metrology suite and teaching and research labs.
http://www.nanowerk.com/nanotechnology/research/nanotechnology_links.php Nanowerk LLC 700 Bishop Street, 17th Floor;Suite 1700 Honolulu , HI 96813 USA	**Welcome to Nanowerk – Enjoy exploring the world's most comprehensive nanotechnology and nanoscience resources** Nanowerk is the premier and most popular source for nanotechnology information. Apart from our unique Nanomaterial Database™, the most extensive industry directory, a packed conference calendar, complete nanotechnology news coverage, and business resources, we offer Nanowerk Spotlight: Our Nanowerk-exclusive nanotechnology feature looks behind the buzz and the hype. What's hot and new from around the globe. Some stories are more like an introduction to nanotechnology, some are about understanding current developments, and some are advanced reviews of leading edge research

Organization	Description
http://www.sse.gov.on.ca/medt/investinontario/en/Pages/resources_nanotechnology.aspx	Broken link
http://www.biotalent.ca/default_e.asp 1100 - 85 Albert Street Ottawa, ON K1P 6A4 Telephone: (613) 235-1402 Fax: (613) 233-7541 Toll-free: 1-866-243-2472	this is a "workopolis" for people in the "bio" field
http://www.nanoontario.ca/index.php?page=news	Same as "Nanotechnology Network of Ontario" above
MaRS Discovery District **Reception** 416-673-8100 **marsdiscoverydistrict@marsdd.com** MaRS Discovery District 101 College St., Toronto ON M5G 1L7 **Chris Stevenson** Director, Communications T 416.673.8104 F 416.673.8181 E **cstevenson@marsdd.com**	MaRS is where science, technology and social entrepreneurs get the help they need. Where all kinds of people meet to spark new ideas. And where a global reputation for innovation is being earned, one success story at a time. [This is a website for entrepreneurs to start a science / technology company or grow a company].
List of Research Centres Connected to U of Toronto	Bahen Centre for Information Technology: MaRS is where science, technology and social entrepreneurs get the help they need. Where all kinds of people meet to spark new ideas. And where a global reputation for innovation is being earned, one success story at a time. Centre for Nanostructure Engineering: This is a facility that scientists can book to conduct research. Centre for Advanced Nanotechnology: Canada's *first* centre for nanotechnology research, formed in September 1997 under the name The Energenius Centre for Advanced Nanotechnology (ECAN) as a result of a generous donation from Energenius Inc., a Canadian company dedicated to advancing nanotechnology research. As CAN's founding member and supporter of the Energenius Chair in Advanced Nanotechnology held by Professor Harry Ruda, Energenius entered into a strong partnership with CAN in promoting the commercialization and spin-off of nanotechnology advances to CAN and to the global market. Strong industrial support, a team of world-leading research scientists and state-of-the-art tools place CAN at the forefront for developing the key enabling technologies, nanoelectronic and nanophotonic applications, in which nanotechnology will make its first major impact - information technologies, advanced manufacturing and advanced materials and processes. Canadian Institute for Photonic Innovations: The Canadian Institute for Photonic Innovations, a Network of Centres of Excellence, brings together the talents of Canadian researchers from universities, government and industry for the purpose of strengthening Canada's position at the forefront of photonics research and innovation in the 21st century. Canadian Institute for Advanced Research: The Canadian Institute for Advanced Research enables Canadian researchers to work on international research teams that are custom built to transform their fields of study.

Organization	Description
	For nearly three decades, CIFAR has embraced a groundbreaking research model that creates knowledge breakthroughs, advances Canada's research community and drives innovation. CIFAR research is aimed at creating knowledge with the potential to change profoundly how we understand our world. Supporting nearly 400 researchers in 16 countries, CIFAR's research model is uniquely suited to long-term, multidisciplinary and collaborative advanced research. CIFAR is a not-for-profit organization, supported by individuals, foundations and corporations, as well as funding from the Government of Canada and the Provinces of Ontario, British Columbia and Alberta. Emerging Communications Technology Institute: ECTI is an interdisciplinary research institute based at the University of Toronto. ECTI provides global university-based leadership through access to state-of-the-art research facilities, promotion of collaborative research with strategic partners, and by facilitating advanced educational opportunities and information exchange events. Key research areas include nanotechnology and nanofabrication, photonic materials and devices, micro- and nanoelectromechanical systems (M/NEMS), biotechnology, microwave devices, micro- and nanoelectronic devices, integrated optics, and photovoltaic devices. Engineering Science Undergraduate Degree in Nanoengineering: The Nanoengineering Option represents the first undergraduate program of its kind in the world, and transcends the traditional boundaries between physics, chemistry and biology. Students learn how controlling shape and size at the nanometer scale enables the design of smaller, lighter, faster and better performing materials, components and systems. Graduates have the potential to radically transform almost any imaginable sector, including health care, manufacturing, information technology, energy and transportation. Nonengineering: Engineering at the University of Toronto once again ranked in 10th place overall among the world's universities and colleges and 1st in Canada, in a recent ranking by the U.S. News & World Report's inaugural World's Best Colleges and Universities of 2008. In 2008, U of T Engineering also ranked 1st in Canada and 10th overall in the world in the Engineering and IT category of the Times Higher Education-QS World University Rankings, up from 11th in the world in 2007. Using data from the Times Higher Education-QS World University Rankings, this is the first ranking of the world's best colleges and universities by U.S. News & World Report. The magazine U.S. News previously produced a U.S. ranking of colleges and universities for the past 25 years. Centre for the Study of Thin Polymer Films for Advanced Properties: The Centre for the Study of Thin Polymer Films for Advanced Properties was established in 2001 to develop new knowledge about the origin of performance of thin polymer films. We develop new approaches for synthesizing new polymers, with catalytic or photoresponsive properties. We will develop new techniques to characterize these materials and a deeper knowledge of the surfaces and interfaces within them. Over the next 3 years, a new generation of materials will be created at the Centre for a broad range of technologies, ranging from microelectronics and optoelectronics, to new catalysts; from bright fluorescent coatings to new adhesives and new lubricants. The Centre is supported by Industry, Ontario Research Challenge and Development Fund and NSERC Canada. Our team is part of a larger materials group using a world-class equipment infrastructure Centre for Quantum Information and Quantum Control: CQIQC is an interdisciplinary Center whose goal it is to promote research in the vibrant fields of quantum information and quantum control. CQIQC's activities at the University of Toronto encompass the Departments of Chemistry, Physics, Mathematics, Computer Science, Electrical Engineering, and Materials Science. Through an extensive external affiliate program, CQIQC promotes collaborations with researchers all over the globe. CQIQC members are

Organization	Description
	involved in a variety of theoretical and experimental activities, including coherent control, quantum optics, quantum cryptography, quantum decoherence-control, and quantum algorithms. The Center was established in April 2004 with internal funding from the President of the University of Toronto, the Vice-President of Research and Associate Provost, the Dean of the Faculty of Arts & Science, and the Dean of the Faculty of Engineering. It further funds endowed postdoctoral fellowships and visiting professorships, organizes conferences, workshops and summer schools, and coordinates the development and teaching of graduate courses in QI/QC, and runs a seminar series.
University of Toronto UT NANOnetwork	The purpose of the NANOnetwork is to leverage the strengths of individual researchers by facilitating cooperation. This involves sharing tools, training and technical insights. Since the early 90s the University of Toronto has been a leader in the field, hosting major conferences and since 2001 providing the world's first undergraduate degree program in nanoengineering.
Brockhouse Institute For Materials Research (BIMR)	The vision behind the Brockhouse Institute is that the very best research is always driven by the imagination of the best researchers. The objective of this Institute is to develop versatile tools at the highest level and provide the infrastructure, access and expertise that researchers require to take full advantage of them in the pursuit of their ideas. The Institute is highly focused on student training with the perspective that the best training is direct involvement in the high-impact research at the cutting-edge of science.
Centre for Emerging Device Technologies (CEDT) Linda Wilson, Administrative Secretary directly at: lwilson@mcmaster.ca By Phone: (905) 525-9140 ext. 27129 By Fax: (905) 527-8409 Mailing Address: C.E.D.T McMaster University JHE A318 1280 Main Street West, Hamilton, Ontario L8S 4L7	The Centre for Emerging Device Technologies (CEDT) is an organization that facilitates study of the optical, electrical, mechanical, and biological properties of semiconductors and related materials and promotes the development of technology based on these materials. In 1987, faculty members of McMaster University founded the CEDT under its original name, the Centre for Electrophotonic Materials and Devices (CEMD), in order to pool resources, enhance facilities, promote industrial collaboration, and advance research. In 2005 the name of the Centre was changed to CEDT to better reflect the diversified range of research topics in which group members have become increasingly involved. Today the Centre is made up of member faculty and graduate students from the Departments of Engineering Physics, Electrical Engineering, Physics, Materials Engineering, Mechanical Engineering, and Chemical Engineering. Six full-time staff operate and maintain equipment for material growth, analysis, and processing, located in four laboratory facilities. We develop lasers, MEMS, detectors, waveguide devices, and much more. Industrial collaborations take place frequently and new initiatives are always welcome.
Queen's Surface Analysis Facility Department of Chemistry Queen's University 90 Bader Lane Kingston, Ontario Canada K7L 3N6 Phone: (613) 533-2616 Fax: (613) 533-6669	The Surface Analysis facility aims to support researchers at Queen's in the field of materials and polymer sciences in sample analysis, particularly those researchers focussing on surface and interfacial aspects of materials chemistry. We also welcome external users.
Ryerson University Analytical Center	Link to the Department of Chemistry and Biology at Ryerson; The Department of Chemistry and Biology houses laboratories devoted to undergraduate instruction in each of the subdisciplines we teach. There are laboratories for chemical instrumentation, chromatography, and for analytical, inorganic, physical and organic chemistry. We also have laboratories specifically designed for biochemistry and microbiology experiments, including gel electrophoresis and DNA sequencing. Facilities for air pollution control and wastewater treatment are also available for the use of students in their undergraduate thesis work.

Organization	Description
Institute for Quantum Computing 475 Wes Graham Way Waterloo, Ontario, CA Phone: 519-888-4021 Fax: 519-888-7610 GPS: Lat 43.47843, Lon -80.55508 University of Waterloo 200 University Ave. West Waterloo, Ontario, CA N2L 3G1	IQC is a scientific research institute at the University of Waterloo exploring and taming the quantum universe to transform computing and communications. The institute's researchers are appointed in the Faculties of Mathematics, Science and Engineering at the University of Waterloo. IQC has assembled a critical mass of researchers and students pursuing a wide variety of theoretical and experimental approaches to quantum information. IQC will continue to build a vibrant knowledge community of researchers who will help establish Waterloo and Canada as global leaders in the quantum information revolution.
Centre for Advanced Photovoltaic Systems Professor Siva Sivoththaman Director-CAPDS, Office: ERC-1001 Department of Electrical and Computer Engineering University of Waterloo 200 University Avenue West Waterloo, Ontario N2L3G1, Canada. Tel: (519) 888-4567 ext.35319	The Centre for Advanced Photovoltaic Devices and Systems (CAPDS) promotes cutting edge research and technology development in all aspects of photovoltaic (PV) energy conversion. Located at the University of Waterloo (UW), right at the heart of Canada's Technology Triangle Area, the CAPDS is a 14000 sq.ft. research facility with dedicated infrastructure for PV research. The CAPDS, occupying the entire ground floor of UW's brand-new Energy Research Centre (ERC) building, supports synthesis of semiconductor base materials, nanotechnologies for PV, design and fabrication of advanced PV devices and modules, and testing and characterization of PV materials, devices and systems. Backed by state-of-the-art infrastructure and expertise, the multi-faceted research at the CAPDS spans the entire spectrum of PV technology, and makes it a unique facility that is capable of making a meaningful impact on the quest for rendering PV affordable as an energy alternative. The CAPDS initiative is funded by the Canadian Federal Government, the Ontario Provincial Government, Industry, and by the University of Waterloo. The CAPDS facility is all set to become fully operational in year 2010.
Interface Science Western	Nearly 25 members, including faculty, technical and research staff, and graduate students in association with the departments of Chemistry, and Physics and Astronomy at the University of Western Ontario combine to form ISW. The diversity of the group allows for a wide variety of facilities to be available to each researcher. Commercial services are also available for the outside community. Interface Science Western is a dyamnic environment continually interested in increasing the resources and potential of the group through Recruiting and Research. Please contact us for further information. ISW is associated with both the Chemistry and the Physics and Astronomy departments of the University of Western Ontario in London, Ontario, Canada.
Western Institute for Nanomaterials	WINS is a Faculty of Science initiative, and will have active participants from the Departments of Physics & Astronomy, Chemistry, Earth Sciences, Biology, Applied Mathematics, and Computer Science. It is anticipated that the membership will be expanded at a later time to include individuals from the Faculty of Engineering and the Faculty of Medicine & Dentistry. Materials and Biomaterials has been designated one of the core theme area in the Academic Plan of the Faculty of Science. The establishment of WINS can therefore be viewed as a natural evolution of the Academic Plan in that the mandate of WINS is to integrate and expand UWO Science's already distinguished efforts in the interdisciplinary fields of materials at the nanoscale. WINS has three main objectives: 1.) To provide a cohesive presence and collective vision for the departments, laboratories and facilities that presently work on nanomaterials. 2.) To develop a graduate program in Materials and Biomaterials sciences. This will be strongly integrated with the undergraduate programs in the same area recently introduced by the Faculty of Science 3.) To serve as an organization where UWO researchers in materials science will be able to meet, interact and collaborate effectively, as as a communication link to the outside world.

Organization	Description
Materials and Manufacturing Ontario (MMO)	Broken link
Ministry of Research and Innovation (MRI)	This is an Ontario Government Ministry
Ontario Centres of Excellence (OCE) **Dr. Tom Corr** President and CEO (416) 861 1092 x1002 tom.corr@oce-ontario.org	The Ontario Centres of Excellence is the pre-eminent research-to-commercialization vehicle in Ontario. We take ideas to income. Created in response to Ontario's most critical competitive challenges, we facilitate economic growth through support for industrially relevant R&D, the opening of new market opportunities and the commercialization of leading edge discovery. We build strong industry and academic relationships. And, we stimulate knowledge transfer through the development of bright minds, moving their skills to the market.
Canada Foundation for Innovation (CFI) Canada Foundation for Innovation 230 Queen Street Suite 450 Ottawa, ON K1P 5E4 Canada Phone: (613) 947-6496 Fax: (613) 943-0923	Created by the Government of Canada in 1997, the Canada Foundation for Innovation (CFI) strives to build our nation's capacity to undertake world-class research and technology development to benefit Canadians. Thanks to CFI investment in state-of-the-art facilities and equipment, universities, colleges, research hospitals and non-profit research institutions are attracting and retaining the world's top talent, training the next generation of researchers, supporting private-sector innovation and creating high-quality jobs that strengthen Canada's position in today's knowledge economy. Funding Formula. The CFI normally funds up to 40 percent of a project's infrastructure costs which are invested in partnership with eligible institutions and their funding partners from the public, private, and voluntary sectors who provide the remainder.
Canadian Institute of Health Research (CIHR) **Canadian Institutes of Health Research** 160 Elgin Street, 9th Floor Address Locator 4809A Ottawa, ON, K1A 0W9 Canada **General Inquiries:** 613-941-2672 Toll Free: 1-888-603-4178 Fax: 613-954-1800	CIHR integrates research through a unique interdisciplinary structure made up of 13 "virtual" institutes. CIHR's Institutes are not buildings or research centres, but networks of researchers brought together to focus on important health problems. Unconstrained by bricks and mortar, the Institute's virtual structure encourages partnership and collaboration across sectors, disciplines and regions. Each Institute is dedicated to a specific area of focus, linking and supporting researchers pursuing common goals. Each Institute embraces a range of research from fundamental bio-medical and clinical research, to research on health systems, health services, the health of populations, societal and cultural dimensions of health and environmental influences on health. This integrated approach brings together researchers, health professionals and policy-makers from voluntary health organizations, provincial government agencies, international research organizations and industry and patient groups from across the country, under each Institute's virtual "roof."
Natural Sciences and Engineering Research Council (NSERC) **NSERC** 350 Albert Street Ottawa, ON, Canada K1A 1H5 613-995-4273	NSERC aims to make Canada a country of discoverers and innovators for the benefit of all Canadians. The agency supports university students in their advanced studies, promotes and supports discovery research, and fosters innovation by encouraging Canadian companies to participate and invest in postsecondary research projects. NSERC researchers are on the vanguard of science, building on Canada's long tradition of scientific excellence.
Canada Nano Portal nanotech@hc-sc.gc.ca	The NanoPortal has been designed to provide single-window access to national and international audiences with information about Canadian Federal Government nanotechnology programs, as well as links to further general information about nanotechnology. Hyperlinks to those external sources are provided solely as a convenience to you and do not imply official approval or endorsement of the sites, their content, the host organizations or their sponsors. When activating these links, you will be temporarily leaving the NanoPortal Web. Here is the link to the NanoRegulations Page from this portal: http://nanoportal.gc.ca/default.asp?lang=En&n=23410D1F-1 -

Appendix C – List of Standards published by CSA, ISO/TC229, and IEC/TC113

CSA Standards - adopted (in Canada) ISO standards

CSA Z12885-12 **Nanotechnologies — Exposure control program for engineered nanomaterials in occupational settings.**
CAN/CSA-ISO/TR 13121:13 **Nanotechnologies – Nanomaterial risk evaluation** (Adopted ISO/TR 13121:2011, first edition, 2011-05-15)

ISO Standards

***Terminology and nomenclature**:*

ISO/TS 80004-1:2010 **Nanotechnologies -- Vocabulary -- Part 1: Core terms**
ISO/TS 27687:2008 **Nanotechnologies -- Terminology and definitions for nanoobjects -- Nanoparticle, nanofibre and nanoplate**
ISO/TS 80004-3:2010 **Nanotechnologies -- Vocabulary -- Part 3: Carbon nanoobjects**
ISO/TS 80004-4:2011 **Nanotechnologies -- Vocabulary -- Part 4: Nanostructured materials**
ISO/TS 80004-5:2011 **Nanotechnologies -- Vocabulary -- Part 5: Nano/bio interface**
ISO/TS 80004-7:2011 **Nanotechnologies -- Vocabulary -- Part 7: Diagnostics and therapeutics for healthcare**
ISO/TR 11360:2010 **Nanotechnologies -- Methodology for the classification and categorization of nanomaterials**
ISO/TR 12802:2010 **Nanotechnologies -- Model taxonomic framework for use in developing vocabularies -- Core concepts**

Measurement and characterization:

ISO/TS 10797:2012 **Nanotechnologies – Characterization of single-wall carbon nanotubes using transmission electron microscopy**
ISO/TS 10798:2011 **Nanotechnologies -- Characterization of single-wall carbon nanotubes using scanning electron microscopy and energy dispersive X-ray spectrometry analysis**
ISO/TS 10867:2010 **Nanotechnologies -- Characterization of single-wall carbon nanotubes using near infrared photoluminescence spectroscopy**
ISO/TS 10868:2011 **Nanotechnologies -- Characterization of single-wall carbon nanotubes using ultraviolet-visible-near infrared (UV-Vis-NIR) absorption spectroscopy**
ISO/TR 10929:2012 **Nanotechnologies – Characterization of multiwall carbon nanotube samples**
ISO/TS 11251:2010 Nanotechnologies **-- Characterization of volatile components in single-wall carbon nanotube samples using evolved gas analysis/gas chromatograph-mass spectrometry**
ISO/TS 11308:2011 **Nanotechnologies -- Characterization of single-wall carbon nanotubes using thermogravimetric analysis**
ISO/TR 11811:2012 **Nanotechnologies – Guidance on methods for nano and microtribology measurements**
ISO/TS 11888:2011 **Nanotechnologies -- Characterization of multiwall carbon nanotubes -- Mesoscopic shape factors**
ISO/TS 12025:2012 Nanomaterials **– Quantification of nano object release from powders by generation of aerosols**
ISO/TS 13278:2011 **Nanotechnologies -- Determination of elemental impurities in samples of carbon nanotubes using inductively coupled plasma mass spectrometry**

Health, safety and environmental aspects of nanotechnologies:

ISO 29701:2010 **Nanotechnologies -- Endotoxin test on nanomaterial samples for *in vitro* systems -- *Limulus* amebocyte lysate (LAL) test**
ISO 10801:2010 **Nanotechnologies -- Generation of metal nanoparticles for inhalation toxicity testing using the evaporation/condensation method**
ISO 10808:2010 **Nanotechnologies -- Characterization of nanoparticles in inhalation exposure chambers for inhalation toxicity testing**
ISO/TR 12885:2008 **Health and safety practices in occupational settings relevant to nanotechnologies**

ISO/TR 13014:2012 **Nanotechnologies – Guidance on physico-chemical characterization of engineered nanoscale materials for toxicologic assessment**
ISO/TR 13121:2011 **Nanotechnologies -- Nanomaterial risk evaluation**
ISO/TR 13329-2012 **Nanotechnologies – Safety Data Sheet (SDS) preparation for manufactured nanomaterials**
ISO/TS 14101-2012 **Surface characterization of gold nanoparticles for nanomaterial specific toxicity screening: FT-IR method**

Material specifications:

ISO/DTS 11931-1 **Nanotechnologies – Nanocalcium carbonate – Part 1: Characteristics and measurement methods**
ISO/DTS 11937-1 **Nanotechnologies – Nanotitanium dioxide – Part 1: Characteristics and measurement methods**
ISO/TS 12805:2011 **Nanotechnologies -- Materials specifications -- Guidance on specifying nanoobjects**

IEC Standards

Performance Assessment:

IEC 62624 Edition 1.0 (2009-08-04) **Test methods for measurement of electrical properties of carbon nanotubes**
IEC/PAS 62565-2-1 Edition 1.0 (2011-03-25) **Nanomanufacturing - Material specifications - Part 2-1: Single-wall carbon nanotubes - Blank detail specification**
IEC/TS 62607-2-1:2012 **Nanomanufacturing - Key control characteristics - Part 2-1: Carbon nanotube materials - Film resistance**

Above list current as of October 2013. See these links for additional standards under development:
ISO/TC229
IEC/TC113

Appendix D - CEQB Draft Nanotechnology Examination Syllabus (May 2013)

INTRODUCTION

The Canadian Engineering Qualifications Board of Engineers Canada issues the Examination Syllabus that includes a continually increasing number of engineering disciplines.

Each discipline examination syllabus is divided into two examination categories: compulsory and elective. A full set of Nanotechnology Engineering examinations consists of ten, three-hour examination papers. Candidates will be assigned examinations based on an assessment of their academic background. Examinations from discipline syllabi other than those specific to the candidates' discipline may be assigned at the discretion of the constituent association.

Before writing the discipline examinations, candidates must have passed, or have been exempted from, the Basic Studies Examinations.

The constituent association will supply information on examination scheduling, textbooks, materials provided or required, and whether the examinations are open or closed book.

NANOTECHNOLOGY ENGINEERING EXAMINATIONS

GROUP A
COMPULSORY EXAMINATIONS

SIX REQUIRED – A1, A3 and A4 PLUS THREE OF THE REMAINING FIVE

13-NE-A1 Quantum Mechanics

Origins of quantum mechanics. Postulates and interpretation of quantum mechanics. Wave functions, Schrodinger equation and their application to one dimensional problems and small particles. Solutions for the harmonic oscillator and hydrogen atom including angular momentum and spin. Concepts and applications of tunneling.

13-NE-A2 Partial Differential Equations

Analytical solutions of partial differential equations. Eigen-functions and eigen-value problems. Special functions in cylindrical and spherical coordinates. Applications drawn from microelectromechanical systems, photonics, quantum mechanics, and/or nanoparticle behavior.

13-NE-A3 Organic chemistry

Structure and properties of organic molecules, NMR, IR spectroscopy and mass spectrometry of organic molecules. Structure, function and reactions of the following organic compounds: carbohydrates, lipids, carboxylic acids, hydrocarbons, amino acids, peptides, proteins, synthetic polymers, biopolymers, nucleic acids, RNA, DNA.

13-NE-A4 Micro- and Nanofabrication

Microfabrication processes for MEMS, microfluidics, and nanostructures. Thin film deposition processes, doping, lithography, and wet and dry etch. Bulk and surface micromachining, and examples of common devices. Scaling, yield, and reliability. Electrical and optical measurement and characterization, and electron and scanning probe microscopies. Self assembly: top-down and bottom-up approaches.

13-NE-A5 Electromagnetics (at the micro and nano scale)

Properties of nanoscale electrical conductors. Transmission and reception of electromagnetic radiation from components based on nanomaterials, electronic nanoscale components, nanoantennas (including examples of current technology), demodulation of electromagnetic waves (e.g. based on electromechanically resonating carbon nanotube). Surface plasmons and applications.

13-NE-A6 Physical Chemistry of Surfaces

Capillarity. The nature and thermodynamics of interfaces. Surface films on liquid substrates. Electrical aspects of surface chemistry. Electrical double layer. Surfaces of solids and characterization techniques. Solid-liquid interface. Contact angle. Adsorption. Adhesion.

13-NE-A7 Semi Conductor Physics

Basic concepts of semi-conductor materials used in the fabrication of electronic components, doping, Fermi level, electron mobility, electrical and thermal conductivity, operations and study of elementary electronic components: diode (PN junction), bipolar transistor and field effect transistor, etc.

13-NE-A8 Biomaterials

Impact of biomaterials, characteristics and classification, surface properties at the nanoscale, surface modifications at the nanoscale, degradation, corrosion, electrical, thermal, mechanical properties of biomaterials. Methods of characterization, biocompatibility, nanoscale phenomena, processing of nanostructured biomaterials, environmental and safety aspects, metallic, ceramic, polymeric and composite nanobiomaterials, nanobiomaterials for tissue regeneration

GROUP B
ELECTIVE EXAMINATIONS

THREE REQUIRED

13-NE-B1 Biochemistry

Basics of microbial and mammalian cell structure and functions, biochemical pathways in aerobic and anaerobic metabolism, kinetics of enzyme-substrate reactions, molecular genetics and protein synthesis, DNA and RNA replication, gene expression, immobilization of enzymes and applications in Nanotechnology. Structure and function of monoclonal antibodies, applications monoclonal antibodies in clinical medicine, biomarkers and nanoprobes, nanoparticle encapsulation of pharmaceuticals for controlled release.

13-NE-B2 Environmental concerns / Ecotoxicology

13-NE-B3 Nanobio – microfluidics

Physics of solids-vapor and solid liquid interfaces. Difference between classical fluid mechanics and micro- and nanofluidics. Electrokinetic phenonmena and zeta potential. Pressure-driven and electrically field driven flow. Interfacial slip flow.

13-NE-B4 Nanoelectronics, Quantum electronics, etc.

Review of quantum mechanics. Free and confined electrons and band theory of solids. Graphene and carbon nanotubes. Quantum dots and quantum wires. Tunneling, junctions, and tunneling devices. Nanotube and nanowire FETs and devices.

13-NE-B5 Nanomedicine

Nanoscale drug delivery, nanosensors, nanoengineering systems for medical therapeutics, nanomedicine for medical imaging and diagnostics, nanopharmaceuticals, nanotechnology for oncology and photodynamic therapy, translational nanotechnology, nanotechnological devices for neurological and neuromuscular disorder, theranostic nanomedicine.

13-NE-B6 Synthetic biology

13-NE-B7 Photonics/optics

Review of geometrical and wave optics. Optical measurements, detectors, and instrumentation. Coherent radiation and lasers. Photonic devices and materials including quantum dots and wells, photonic crystals, displays, and photovoltaic cells.

13-NE-B8 Computational Methods in Micro- and Nanotechnology

Finite element methods, lattice Boltzmann method, computational fluid mechanics, computational solid mechanics, molecular dynamics, computational micromagnetics, computational chemistry.

13-NE-B9 Nanotechnology in Alternative Energy

Nanostructured materials in fuel cell and solar cells, electrical double layers, supercapacitors and superconductors.

Appendix E - Target Domains

There is merit is defining "Target Domains" (TD) within engineering disciplines and industry sectors when they are needed over time.

This concept is analogous to the concepts in marketing of ‘market segmentation’ and product differentiation’. Broad markets (say ‘shampoo’) are subdivided by a manufacturer into targets that help distinguish its specific product in the market (e.g: shampoo for dandruff or for soft hair etc). This idea of ‘products developed for a target market is extended for the practice of occupations and is inherent to a particular practice. Hence, physicians learn a set of skills that they apply to the human body as their target domain. Veterinarians learn very similar skills but these are applied to the non-human animal domain. Within these there can be further sub-divisions, for example, a physician can be a brain specialist meaning his/her target domain is the human brain. Suggested TD’s for NME are in the main text.

There is nothing mandatory about this concept, it is simply a mechanism to assist in organizing how to govern the profession, much like subdividing a geographic region into provinces and counties to assist in political governance. Hence, domains will change as technology develops.

More than one discipline (or specialty) can have the same Target Domain. For example, the Target Domain ‘Medical’ is an important TD for electronic instrumentation engineers (part of the disciplines of Electrical Engineering and Bio-Engineering) who have designed all of the modern day electronic tools typically used in hospitals. It is also a target domain for CIE for equipment (“things”) that also include an IP communication capability and hence are exposed to the world. Such equipment can suffer from potential disruption by external attackers (‘hackers’, 'cyber terrorists').

Very clearly, the medical field is of high importance to NME where it is possible to design new medical cures using this technology. Notice that not only is the TD overlapping here, but it is very likely that specific equipment is the target interest of more than one discipline of engineering. This is not unusual and should be expected. The target domain of ‘buildings’ for example, is the TD for Civil, Structural, HVAC (Mechanical) engineering, Electrical power and others. Though the TD’s may be the same, each practice discipline does different things.

From the point of view of an individual discipline, defining relevant TD’s to that discipline assists in defining where that discipline plays a critical role in serving and protecting the public interest. While each discipline will have many TD’s, PEO will only need to explicitly define and name those with the most relevance to the public interest. For example, Software Engineering can name the energy industry and the gaming industry as TD’s. Clearly, using software in the control of a Nuclear Reactor will have more public interest than the software in a Smart-phone game. When PEO explicitly declares that the power industry is a TD for Software Engineering, it is saying that practicing software engineering in the electrical power industry is an exclusive area of practice for that discipline. In other words, to practice software in the power industry one MUST have a P.Eng. (and clearly be skilled in software practice as our code of ethics requires) in addition to the Electrical Engineering competence on power systems.

This last statement is the key point. It is all about recognizing where the bounds are to a practice in Engineering. As much as we engineers like generalizations, our courts of law do not work that way. A judge will only understand specifics. A TD helps to be specific in defining what is part of engineering practice.

The following summary definition captures the essential nature of the TD:

A Target Domain:

- Is a pragmatic, organizational construct to assist PEO in the governance of the profession, taking into account the level of public safety impact to assist in prioritizing :
    - informs compliance actions by the Enforcement Committee and
    - informs guideline roll-out by the Professional Standards Committee.
    - informs demand Legislation activities by the Legislation Committee
- Defines an activity where a specialized engineering skill set is required;
- Is bounded in scope;

There is difference between a TD and an Engineering Specialization. The TD is defined by the physical boundaries of the engineering practice or industry. A specialization is defined by a skill set driven by its utility in a given practice.

We will often see the two ideas combined. For example, the BDS (Building Design Specialist) is an engineer with a Civil/Structural engineering skill set who does designs of building structures. So a BDS engineer will not do a bridge design though he/she has the fundamental skills to do so.

A 'specialty' can be as broad as an entire discipline. E.g.: Software Engineering Specialist. By defining where that practice shall occur with a TD, we narrow the focus of the public interest impact. PEO must serve and protect that interest. In short, TD's assist in the management of regulating and governing engineering practice.

Examples of industry TD's are: Pharmaceuticals, Medical, Mining (ore extraction, comminution (grinding), flotation, smelting, refining), power generation (including Nuclear) and distribution, manufacturing, etc.

In this context, the new engineering disciplines of NME, CIE and Software Engineering are, indeed, Disciplines, not TD's.

In NME, example TD's may be:

- Medical field, and
- Pharmaceuticals.

In CIE, example TD's may be:

- Energy Sector (SMART Grid: power generation and distribution communication and control);
- Finance Sector;
- Medical (remote communication and control of medical devices); and
- stock market.

In Software Engineering, example TD's may be

- nuclear reactor control;
- medical instruments control (embedded software);

(see Software Engineering phase 1 and 2 reports)

How PEO defines or re-defines a TD will change over time and necessities. As new technologies are created new perspectives on TD's will emerge to assist in partitioning the task of regulating the practice of engineering.

Summary

Fundamentally, TD's provide a method to help in regulating the profession by dividing the problem which is a standard engineering technique. Declaring that Electrical Engineering is an exclusive area of engineering practice may be correct but implementing this on a broad scale is very difficult. We tend to end up with nothing being regulated or enforced because the task is so broad. Establishing a TD of Nuclear Power for example, allows PEO to not only declare but now to enforce the mandate that ONLY a P.Eng. with an Electrical Engineering skill set is allowed to design, opine, report, operate etc, Nuclear power equipment. This is very specific and focused. A judge can easily follow this and determine if an individual was practicing engineering or not. It is also specific enough for PSC to write a guideline on critical factors for Electrical Engineering practicing within the Nuclear Power Industry TD.

TD's can be as broad or narrow as desired and these in turn can be subdivided. It is all a matter of where there is large public interest impact. The concept provides a regulatory tool refinement and flexibility in carrying out PEO's mandate.

Appendix F – Information and Guidance for Practitioners

Commercial scale plants

NME brings a number of commercialization issues that practitioners must be aware of, most of which relate to these scenarios:

- the scale-up of nanomaterial production from laboratory plant to pilot plant,
- the scale-up of nanomaterial pilot plant to commercial scale production unit,
- the use of nanomaterials in various plants as process and/or product components, reaction catalysts, etc.

In principle, all engineering design, development, manufacture and operation of commercial process plant is already regulated under the Act. However, the addition of the nanomaterials adds the requirement for licensed NME engineers to ensure public safety above and beyond traditional "process and manufacturing engineering".

A list of typical areas requiring NME attention in the above scenarios are noted below (not ranked, some overlap):

- Design for overall plant and process security and safety
- Fail safe under any eventuality (internal or external) down to low probability events at the given location
- EPCM practices
- HAZOP review protocols
- Health and safety protocols
- Materials handling
- Maintenance protocols
- Effluent treatment, including nanomaterial effluent (all phases)
- Environmental protection
- Mechanical standards
- Seismic event robustness (for the location)
- All power fail modes (part of HAZOP)
- Security against terrorist and/or political activist attack (risk and type to be evaluated)
- Process construction standards
- Measurements, monitoring and real-time control (including alarm and safety interlock data)
- Management information system protocol
- Historical record storage (plant data)
- Security of persons and equipment
- Design of process equipment units and components.

We expect that generalized process plant in various industries will increasingly contain "NME domains" as part of on-going product and process improvements. Although most of the process engineering work will still be carried out by the "traditional" engineering disciplines, there is an additional requirement in NME domains for NME engineers to ensure that safety requirements demanded by the process's nanomaterial content be addressed at each stage of evolution from laboratory to production. Such design and operational interventions range from equipment module design to the control and monitoring of the full scale process plant and its ongoing maintenance.

Practitioner considerations

Professional Engineers not previously licensed in NME who wish to practice in this area should refer to the Core Body of Knowledge, Professional Practice Guidelines and/or the ARC board sheet to determine the technical knowledge requirements for NME practice in order for their self-assessment of competency to begin practicing in the field.

Appendix G - The Accelerating Pace of Change

> "*As we move into the 21st century, we come from a remarkable past century of amazing technological progress. Yet this pace of change is not slowing down. If anything, it is accelerating. It appears that each new scientific discovery raises several new avenues for discovery.*"[51]

This accelerating change has direct implications for both NME with respect to new products released on the public, and, for PEO as it attempts to govern and license all new forms of engineering that have a significant "public interest (wellbeing)" impact.

Consider the following indicators of the pace of change to gain a sense of how fast change is now occurring. In 1970, it cost $150,000 to transmit 1 trillion bits of information (a small library). By 1999, the cost 12 cents![52]

Figure 1- Moore's Law shows computing capabilities double about every two years while cost, size and energy consumption decrease. This trend traces back at least to the invention of the transistor in 1952 and is predicted to continue to at least 2030. As can be seen, new nano components will assist in creating the new computing devices.

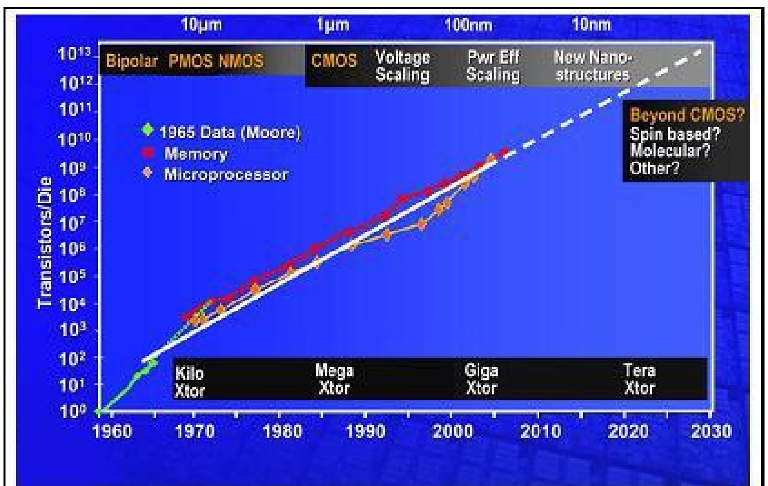

Figure 1- Moore's Law[53]

This creates a technology pervasiveness never before seen in the history of humankind. Software, the Internet, Cell phones are all dependent on this underlying technology that is driving our modern world.

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2. **"A Search for Advocacy - Creating the Canadian Engineering Profession"**, by Peter M. DeVita. P.Eng. ISBN: 978-1-927389-00. G7 Books, available through **amazon.ca** or at **http://www.g7books.com/search4.html; p 51**

[52] Prof. Michael M. Tseng Federal Reserve Bank of Dallas Vertical Industry Structure and Integral Product The Bank Credit Analyst 2004.28

[53] Sunlin Chou, "Innovation and Integration in Innovation and Integration in the Nanoelectronics Era. ", Technology and Manufacturing Group, Intel Corporation Intel
International Solid State Circuits Conference, February 2005;
ftp://download.intel.com/technology/silicon/Sunlin%20ISSCC%20020705%20foils.pdf

> *"Since the first deployments of fiber-optic communication systems three decades ago, the capacity carried by a single-mode optical fiber has increased by a staggering 10,000 times."*[54]

As well as technology growing at ever faster rates, humans have also adopted new technologies faster. Figure 2- Diffusion of Various Technologies and Figure 3- Diffusion over time show this accelerating rate of technology adoption.

This increasing pace of change brings urgency to managing the impact of new technology on society. The steps to establish a new discipline are equivalent to establishing a totally new licensing regime. I 1922 APEO recognized five disciplines. We now recognize over 30 which suggest we will see a new practice less than every five years!

As we look to the future, we will have more new areas of practice compounding engineering governance. At some point, PEO will need to address the larger question on how PEO Council members can intelligently govern an ever expanding profession with prudent policies applicable to every new discipline as well as existing ones.

The engineering profession, unlike most others, experiences expanding growth in new unique disciplines. A surgeon with a stainless steel knife or a modern laser is still performing surgery but the engineering of those instruments is radically different.

The profession is just coming to recognise a new dynamic unprecedented in human history. It is a challenge to establish just one licensed practice with proper exclusive rights to practice. We now expect to do this every five years.

Our current structure is designed for a static set of disciplines. This needs to change.

Emerging Disciplines represent the profession's most significant challenge at all levels. As time moves on, the issues will compound, stretching our abilities as humans to govern this ever expanding profession.

In the mean time, practices like NME will follow the same accelerating trends in the numbers of products produced and the varied risks.

[54] http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6170861&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F5%2F6183031%2F06170861.pdf%3Farnumber%3D6170861

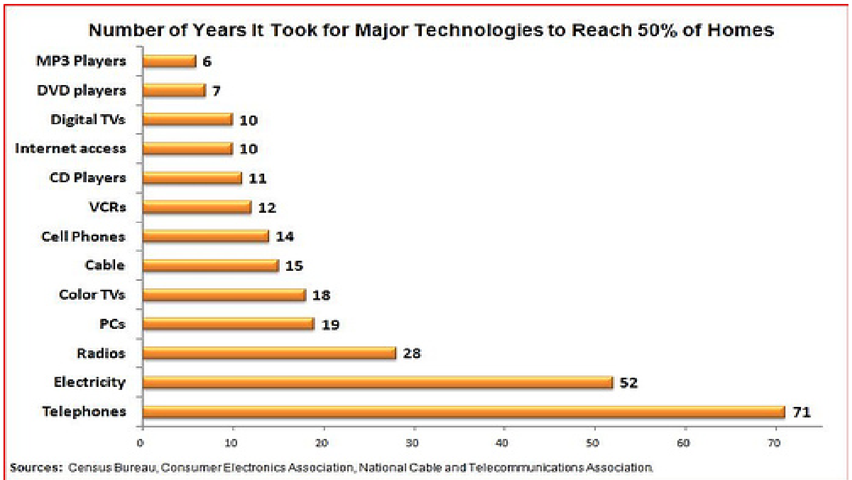

Figure 2- Diffusion of Various Technologies[55]

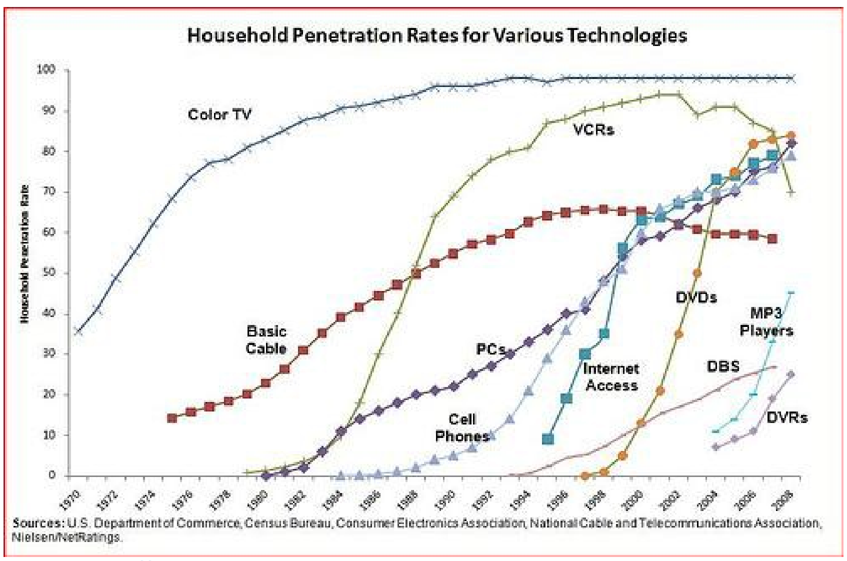

Figure 3- Diffusion over time

[55] http://techliberation.com/2009/05/28/on-measuring-technology-diffusion-rates/ and http://www.cato.org/pubs/pas/pa364.pdf

Appendix H - NME Experience Requirements Criteria

The PEO Experience Requirements Guide defines acceptable engineering experience criteria as the following:

1. Application of Theory
2. Practical Experience
3. Management of Engineering
4. Communication Skills
5. Social Implications of Engineering

Application of Theory

Area	PEO Definition	NME-specific Experience
Analysis	Including scope and operating conditions, performance assessment, safety and environmental issues, technology assessment, economic assessment, reliability analysis.	Risk assessment of nanomaterials including basic lifecycle Performance assessment of nanomaterials in applications
Design and Synthesis	Including functionality or product specification, component selection, integration of components and sub-systems into larger systems, reliability and maintenance factors, environmental and societal implications of the product or process, quality improvements.	Basic experience with design of nano or bio-systems or sensors Process or quality improvements for nanomaterials production
Testing Methods	Including devising testing methodology and techniques, verifying functional specifications, new product or technology commissioning and assessment.	Testing of nanomaterials or nano/bio systems Detection of nanomaterials
Implementation Methods	Including applying technology, engineering cost studies, optimization techniques, process flow and time studies, cost/benefit analysis, safety and environmental issues and recommendations, maintenance and replacement evaluation	Environmental impact assessment of nanomaterials or materials containing nanomaterials Lifecycle risk assessment of nanomaterials used in designs or produced Already above

Practical Experience

Area	PEO Definition	NME-specific Experience
Limitations	Experience and understand the limitations of practical engineering and related human systems in achieving desired goals, including, for example, limitations of production methods, manufacturing tolerances, operating and maintenance philosophies.	Basic experiences with limitations of present manufacturing methods related to nanomaterials Hands-on development of nanomaterials or bio-systems production methods
Knowledge of Codes and Regulations	Opportunities to acquire knowledge and understanding of codes, standards, regulations and laws that govern applicable engineering activities	Basic knowledge of guidance documents related to nanomaterials including, but not limited to: BSI PD6699-2:2007,*Guide to safe handling and disposal of manufactured nanomaterials* CSA Z12885-12 Nanotechnologies – Exposure control program for engineered nanomaterials in occupational settings CAN/CSA-ISO/TR 13121:13, Nanotechnologies – Nanomaterial risk evaluation ISO/TR 13014:2012 Nanotechnologies -- Guidance on physico-chemical characterization of engineered nanoscale materials for toxicologic assessment Policy Statement on Health Canada's Working Definition for Nanomaterial

Social Implications of Engineering

Area	PEO Definition	NME-specific Experience
Safeguards	Safeguards in place to protect the employees and the public and mitigate adverse impacts	Risk assessment of nanomaterials including basic lifecycle Performance assessment of nanomaterials in application

Guidelines for Experience

With regards to the NME-specific experience outlined in the preceding section, it is recommended that the following timeframes would be the minimum ones for licensure.

Area	Recommended Minimum Number of Years Experience	Comment
Application of Theory	1-2 years	Experience should include some examples of lifecycle assessment.
Practical Experience	2-3 years	Experience should include laboratory production experience.
Social Implications of Engineering	2-3 years	Experience should include risk assessment with exposure to standards.

It is expected that for Social Implications of Engineering, a practitioner would have some formal risk assessment training and subsequent application of this training. Applicable standards include, with others under development:

- CAN/CSA-ISO 31000-10 - *Risk management - Principles and guidelines*
- CAN/CSA-ISO 14971-07 - Medical Devices, Application of Risk Management to Medical Devices
- CAN/CSA-ISO/TR 13121:13, Nanotechnologies – Nanomaterial risk evaluation

Updating of the International Engineering Alliance professional competencies may be required for including NME practitioners.[56]

[56] International Engineering Alliance, Graduate Attributes and Professional Competencies, 2009. http://www.washingtonaccord.org/IEA-Grad-Attr-Prof-Competencies-v2.pdf