AC 2009-1708: STRENGTHENING THE U.S. ENGINEERING WORKFORCE FOR TECHNOLOGY INNOVATION: A TIME FOR GOVERNMENT AND INDUSTRY TO INVEST IN A NATIONAL COMPETITIVE STRATEGY TO REVITALIZE U.S. ENGINEERING INFRASTRUCTURE FOR INNOVATION

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Strengthening the U.S. Engineering Workforce for Innovation: A Time for Government and Industry to Invest in a National Competitive Strategy to Revitalize the U.S. Engineering Infrastructure for Innovation

1. Introduction

This is the fourth of four invited papers prepared for the special panel session of the ASEE-National Collaborative Task Force on Engineering Graduate Education Reform. This paper addresses the importance for federal government and U.S. industry to invest in a national demonstration project with innovative universities across the country to accelerate the development of professional master of engineering and doctor of engineering programs that meet the needs of engineers in industry in bolstering U.S. technological innovation for the nation's future economic growth, global competitiveness, and national security.

1.1 Benchmarking National Strategies

Today, as the United States competes in the global economy, its industries are facing fierce competition globally. Other nations are challenging U.S. technological leadership by instituting national policies targeted on innovation. As the National Research Council (NRC)-Committee on Comparative Innovation Policy points out, Governments around the world are taking active steps to strengthen their national innovation systems and are recognizing that a capacity to innovate and commercialize new high-technology products is increasingly a part of their international competition policies for economic leadership.[1]

These nations recognize that developing their indigenous capacity for technology innovation is the key to their competitive advantage. Nations such as China have already placed into policy the importance of nurturing indigenous technology innovation as the core ingredient of their future economic development. As Alan Wolf, member of the NRC-Committee on Comparative Innovation Policy points out, China's drive toward innovation has been an unmistakable message of its top leaders for several years:

> *"In today's world, the core of each country's competitive strength is intellectual innovation, technological innovation and high-tech industrialization." [Jiang Zemin]*
>
> *"[We should give] priority to independent innovation in S&T [Science and Technology] work, take efforts to enhance S&T innovation capability, increase core competitiveness and [strive to make] S&T innovation with Chinese characteristics a reality …*
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> *…We must aim to be at the forefront of the world's S&T development, speed up the building of [a]national innovation system, …strengthen the coordination of economic policies and S&T policies, [and] create a policy environment beneficial to technological innovation, high-tech development and industrialization." [Hu Jintao]*

Other nations are not standing still. Nations from other competing economic groups, such as the European Union (EU), are also promoting their indigenous capacity for technology innovation in their national interest through major government sponsored partnerships between government, higher education, and industry. Toward this aim, the UK government has already taken forward thinking steps during the last 10 years to deliberately advance its engineering infrastructure for innovation through purposeful advancement of postgraduate professional education at both the professional master's and professional doctoral levels of engineering. These investments have been substantial; and they have been successful.

To date, the UK government has invested over 200 million dollars in creating innovative professional Master of Engineering (M.Eng.) programs [called Teaching Company Schemes] in partnership with industry and in the start-up of 20 Graduate Centers leading to the professional Engineering Doctorate (Eng.D.).[2] The postgraduate doctoral centers have been in operation for the last ten years. Both the professional master and the professional doctoral programs are specifically designed to be more relevant to the creative practice of engineering for innovation and are intended to further the skill-sets of graduates expected to pursue careers in industry where technological competitiveness primarily occurs.

1.2 "People … The Heart of Successful Innovation"

Underpinning the UK's effort to improve its competitive edge are three core themes: 1) Innovation is the life-blood of UK's future economic prosperity and improvement of the quality of life; 2) People … are the heart of successful innovation, and; 3) Government creates the conditions for innovation to flourish.

Accordingly, the objectives of the UK professional postgraduate programs in engineering are three-fold:

a) First, the primary aim is to enhance the competitiveness and wealth creation capacity of the UK economy by the stimulation of technological innovation in industry through further postgraduate professional education of engineering graduates who are preparing for careers in industry, and interactive partnership between the university and industry in the graduate's required innovation project during his or her course of postgraduate study.

b) Second, the UK post-graduate programs provide an effective mechanism to further develop UK graduate engineers for world-class innovation, and enhance their potential careers in industry as emerging leaders and innovators. At the core of both the professional masters of engineering and professional doctor of engineering programs are innovation projects that are central to the strategic development of the company partner's competitiveness.

   Each project is guided by a multidisciplinary team consisting of the graduate and senior staff from both the sponsoring company and the university faculty. The aims of each project are to: 1) improve the competitiveness of the company partners; 2) enhance the skill-sets and careers of the graduate(s), and; 3) increase the knowledge base relevance of the UK university partners to industry.

c) Third, the postgraduate professional programs are practice oriented and not only help to build a stronger nationwide engineering infrastructure for more effective engineering innovation within industry across the UK, but also a stronger mechanism for engagement of higher education in the advancement of professional engineering education dealing with practical affairs of industry and society.

Based upon the demonstrated success of these postgraduate practice-oriented doctoral centers, the UK is investing an additional 200 million dollars in 2009 to establish 20 additional postgraduate centers across the country [10 million per center] ─ bringing the total to 40 Graduate Centers across the UK that will offer postgraduate professional education leading to the professional Engineering Doctorate.[3]

2. Rebuilding America's Innovative Capacity ─ Renewal of U.S. Engineering Talent for Innovation in Industry

2.1 Pace of U.S. Innovation

As the United States competes in the innovation-driven economy, the primary responsibility for the systematic creation, improvement, and development of new, improved, and breakthrough U.S. technology and its innovation into useful products, processes, systems, and operations depends on that small group of experienced men and women in industry and mission-oriented government service who understand the fundamentals of engineering and are skilled in the purposeful techniques of the creative practice of engineering for technology development and innovation and its responsible leadership. As Akio Morita, former chairman of SONY Corporation, pointed out: "Knowing how to make the best use of your engineers will be the test of whether a company will succeed in the coming age … Technological management will be the key to success for companies any where in the world, in the coming years." [4]

2.2 U.S. Engineering Progress Is Essential To U.S. Competitiveness

Recognizing that postgraduate education is a key factor in developing their domestic engineering talent for creative careers in industry, other nations are ***not*** standing still in developing their graduate engineers through the professional Master and Doctoral levels of engineering in order to increase their competitive technological advantage.

Thus, it is the sense of the National Collaborative Task Force that if we are to improve our own competitive position in the global economy and raise our leadership capacity for technology innovation, then we as a nation must invest as much as other competitor nations in developing our own domestic creative engineering talent, and provide opportunity for high-quality postgraduate professional engineering education that supports the further growth of our graduate engineers in U.S. industry though the highest professional levels of engineering and its responsible leadership.

To meet the challenge, the ASEE-National Collaborative Task Force on Engineering Graduate Education Reform was deliberately founded in 2000 by leaders of the ASEE-Graduate Studies Division, Corporate Members Council, College Industry Partnership Division, and leaders from industry and universities across the country to define, develop, and implement a high-quality and coherent system of postgraduate professional education for working engineering professionals in industry, as a complement to the existing research base, that:

- reflects the modern process and systematic practice of engineering for the deliberate creation, development, and innovation of new needed technologies for the advancement of U.S. competitiveness, improvement of economic growth, national security, and quality of life

- provides opportunity that fosters the creative, innovative, and leadership capacity of the employed U.S. engineering workforce through the professional master's and professional doctoral levels of engineering levels of proficiency, and better supports the lifelong developmental process by which experienced professionals learn, grow, and develop through all stages of growth, beyond entry-level, for increasing leadership roles of engineering responsibility [I through IX] in America's industry

This is a bold educational initiative and challenge, but the United States is in a good position to make this unique educational innovation happen through strong collaborative partnership between federal government, America's industry, and a coalition of innovative universities across the country responding in the common national interest.

2.3 Where We Are ... And Where We Need To Be

During its investigations, the National Collaborative Task Force has studied the long-term National Goals for Science and Technology and the existing posture of U.S. engineering education to meet those goals. [5]

- ***Finding 1. Engineering Is A Creative Problem-Solving Profession.*** First, it is now evident that U.S. engineering education is undergoing needed transformative change. The U.S. system of engineering education has initiated concerted effort at the undergraduate level to re-strengthen and refocus engineering as a creative problem-solving profession.[6,7,8,9]

  As Wm A. Wulf, former president of the National Academy of Engineering, pointed out in his 2002 plenary address to ASEE — "Today's engineering schools are not preparing their graduates as well as they might for useful practice in the 21st century."… "There is a clear disconnect between the practice of engineering and what is being taught … and, there is urgency for reform."[10] Although Wulf's remarks focused primarily on engineering education at the undergraduate level, urgency for immediate corrective action is required at the graduate level as well to re-strengthen engineering education for the practice of engineering for working professionals in industry.

  As the 1995 National Academy's Committee on Science, Engineering, and Public Policy (COSEPUP) Report, Reshaping the Graduate Education of Scientists and Engineers, pointed out: the U.S. system of engineering graduate education has evolved during the last four decades primarily as a research-oriented endeavor, largely as an outgrowth of the 1945 U.S. science policy.[11] As a result of the 1945 Vannevar Bush Report *Science the Endless Frontier*[12], the nation invested substantially during the 1960's, 70's, 80's, 90's [and must continue into the 21st century] in establishing preeminence of the U.S. system of research-oriented graduate education for further graduate education of U.S. scientists for world-class academic research and 'scientific discovery' at the nation's universities. However, the U.S.

has not made a parallel investment and balanced educational emphasis for the implementation of professional graduate engineering education for the vast majority of the nation's engineers who are not pursuing research-oriented scientific careers but rather who are pursuing professional careers in industry and government service for the advanced practice of engineering for the deliberate generation of needs-driven, technology development and innovation for economic competitiveness or national security purposes.

This long-term 'disconnect' ─ occurring over the last several decades between U.S. engineering graduate education and the creative practice of engineering ─ has contributed to a long-term underdevelopment of the nation's graduate engineers for technology development and innovation, reflected in a long-term decline of our core competence for engineering innovation of new technology which has been a contributing factor to the nation's long-term decline of U.S. competitiveness. It is now evident that one-size of graduate education for the nation's academic scientific researchers, who are pursuing careers of scientific discovery and inquiry at research universities, and that of graduate education for the nation's graduate engineers who are pursuing professional careers of advanced engineering practice for technological development in industry does not fit all.

- ***Finding 2. Lifelong Learning and Postgraduate Professional Education for Engineering.*** Second, as the ASEE-Green Report pointed out ─ "While U.S. engineering education has served the nation well, there is broad recognition that it must change to meet the challenges of the new world of engineering."[13] These changes require a fundamental change in our thinking about engineering education itself ─ both in context and in process ─ as something more than the transmission and acquisition of knowledge from teacher to student ─ but rather as a process that facilitates and enables continuous development of the engineer's fullest intrinsic potential for creativity, innovation, and responsible leadership in meaningful engineering works.

  As recognized by the professional engineering societies and U.S. government, there are nine increasing levels of leadership responsibilities, autonomy, skill-sets and capabilities in the practicing profession of engineering beyond beginning entry-level[14]. Today, undergraduate engineering education serves as the basic educational foundation to prepare the graduate engineer for entry into the practice of engineering at Level I Engineering and as the foundation for further lifelong learning and growth. Further advanced studies, self-directed learning, and progressive engineering experience, insight, and accumulated wisdom ─ gained through actual performance in creative engineering works ─ is required for the graduate engineer to grow beyond beginning entry-level attributes to attain the knowledge, skill-sets and professional attributes necessary for advanced levels of responsible leadership in the practice of engineering for technology development and innovation.

  Thus, it is the sense of the National Collaborative Task Force that an engineer's professional education should no longer be misconstrued as a one-time event limited to four years of undergraduate engineering education … but as a process of lifelong learning and professional development that extends throughout the graduate's entire career and productive years of creative professional engineering practice extending through managerial and executive engineering leadership levels. As the Green Report noted: "Federal agencies that fund education should help universities and their industrial partners identify creative approaches to lifelong learning by funding pilot projects and experiments. … Engineering colleges should create innovative advanced degree programs, including practice-oriented degrees. Such degree programs might include course material on engineering systems; finance and accounting; and technology policy, management and decision-making."

- ***Finding 3. A Paradigm Shift in the Modern Practice of Engineering for Innovation.*** Third, it is now evident that the modern paradigm of the process and practice of engineering for purposeful, systematic technology development and innovation has itself changed substantially during the last half-century[15]. Yet, with notable exceptions, the mainstream of U.S. engineering graduate education has not reflected this change. As Eric Walker, former president of Pennsylvania State University and ASEE, pointed out: "Teaching Research Isn't Teaching Engineering … The key idea is that engineering is a system of [leadership] that results in the satisfaction of human needs … The effectiveness of an engineer is measured by how well he or she … invents and innovates."[16]

  Whereas ***both*** U.S. Science and Engineering enterprises are vital to the national innovation system, they have been funded and treated in the past as if they were linear, sequential pursuits. They are ***not*** … Science and Engineering are ***two*** very different types of pursuits with very different missions, purposes, and methods. In today's innovation-driven economy, the vast majority of engineering innovations are needs-driven and market-focused, requiring deliberate engineering problem solving and responsible leadership. Today, the practice of engineering for creative technology development and innovation is a purposeful and systematic process.

  The linear model of engineering practice for the development of technology, portrayed by 1945 U.S. Science Policy, is now seen to be in error. As the Department of Defense study, *Project Hindsight,* pointed out within 10 years of the Bush Report, the linear-research driven model of technology development is in error.[17] Technology development simply doesn't work that way. Although basic scientific research is frequently needed in large, complex scale technology development and innovation projects, basic research is not the primary forerunner of technology. Creative engineering projects in industry frequently drive the need for directed academic research efforts at universities, when necessary, or when anticipated, to gain a better understanding of the natural phenomena involved.

  As Sanders and Brown have pointed out: "The great discovery of our age is that technological innovation need not be haphazard. Industry and government have developed a new concept of planned and systematized innovation, founded on vastly expanded scientific and engineering efforts. These institutions are now making regular provision for the occurrence of new and unpredictable developments. In fact, "the [creation] of systematized innovation may turn out to be a qualitative change in the economy — one having the same importance for future growth as the development of the concept of capital investment itself had during the past two centuries."[18]

Engineering is primarily a needs-driven activity, and a very creative process and practice, requiring a different mission, purpose, and method from that of research: necessitating a very different type of higher education at both the undergraduate and the graduate professional levels to develop the necessary attributes and talents required of graduate engineers in modern practice. Overemphasis on one part of the Science and Engineering equation for new technology does ***not*** ensure success of the other.

Misunderstanding between Science and Engineering in the total process of innovation, has itself been a contributing factor to America's long-term underdevelopment of the U.S. engineering workforce for innovation, contributing to a long-term loss of engineering leadership for innovation at too many companies that is required today if America's technology-based organizations are to survive, to innovate, and to compete effectively in the global innovation economy. But the problem remains. As COSEPUP has pointed out: "There is no clear human-resources policy for advanced scientists and engineers, so their education is largely a byproduct of policies that support research. The simplifying assumption has apparently been that the primary mission of graduate programs is to produce the next generation of academic researchers. In view of the broad range of ways in which scientist and engineers contribute to national needs, it is time to review how they are educated to do so."

- ***Finding 4. Regional Innovation: The Lifeblood of U.S. Competitiveness.*** As the National Academy's Committee (COSEPUP) noted, while the basic structure of graduate education is sound, some changes are warranted in order to respond to "changing national policies and industrial needs." But more of the same isn't the answer. As Deborah Van Opstal, vice president of the Council on Competitiveness, has pointed out: "The nation must do more to give people the skills they will need in our evolving economy … Skills and education will be a dominant, if not decisive, factor in the United States' ability to compete in the global economy."[19]

  As Christopher Hill points out: "Simply redoubling our efforts to fund more research and to prepare more scientists and engineers along the models of the past is unlikely to be sufficient to meet the new needs … it is not so much that we need more scientists and engineers but that we need new kinds of scientists and engineers."[20] It is the sense of the National Collaborative Task Force that deliberate, planned advancement of postgraduate professional education which focuses on enabling the nation's engineers to acquire the skill-sets they need through coherent programs of practice-oriented postgraduate professional education for innovation shows great promise to meet the challenge.

  As the National Academy's Committee (COSEPUP) has pointed out: graduate education for the nation's scientists and engineers must be broadened. This is especially relevant to this initiative in improving professionally-oriented graduate education for the majority of the nation's engineers, who are pursuing professional careers of creative engineering practice oriented toward the deliberate creation, development, and innovation of new technologies responsive to real-world human needs. Of the 70,000 newly minted graduate engineers who graduate each year, a few will stay at the universities to pursue graduate studies for academic research careers, but most will enter regional industry across the nation in a spectrum of technologies. Further development of these graduate's in America's industry is the lifeblood of the nation's future inventions, improvements, and engineering breakthroughs. Regional industrial innovation is the backbone of U.S. technology competitiveness and a key factor in sustaining employment and creating new jobs.

- ***Finding 5. A National Skills Strategy: Transforming Postgraduate Education for Engineers.*** Fifth, as unexpected parallel outcomes of investigating the need for reform of engineering graduate education for competitiveness in both the UK and the US, the UK Parnaby Committee and the US National Collaborative Task Force have basically reached similar conclusions from essentially two parallel efforts and from two different national perspectives:

a) UK Parnaby Report

As a result of successfully implementing new professionally-oriented engineering graduate education programs at the Masters of Engineering skills level throughout the country ─ through the Teaching Company Scheme (TCS) to stimulate nation-wide innovation ─ the UK government also tasked John Parnaby (Lucas Industries) to set up a committee to also consider improvement in engineering graduate education at higher levels to improve UK prosperity and competitiveness.[21] The recommendation of this committee was that professional Doctor of Engineering (EngD) programs should be instituted as follow-on to the successful Masters programs developed in partnership between industry and universities.

In its recommendations, the Parnaby Report summarized ─

> *"The major conclusion of the Working Party is that there is a need for a major new scheme providing engineering doctorate programmes in the processes and practice of engineering required by industry … Such an engineering doctorate would be distinct from, and complementary to, the traditional existing PhD, which has been criticized for its lack of industrial relevance" … and … "too narrow and academic for industry's needs."*

> *"The evidence collected overseas and from the Total Technology programme in the UK, indicates that these sectors of industry would benefit from a more industrially oriented engineering doctorate. Indeed we believe that the whole of the engineering industry in the UK would benefit greatly from the introduction of such a doctorate."*

b) US National Collaborative Task Force

As a result of its investigations, the US National Collaborative Task Force also concludes that a new, but distinctive American approach is needed for the post baccalaureate professional education of graduate engineers in the United States that supports the American model wherein the majority of US graduate engineers pursuing professional careers do not stay at universities but enter industry or government service immediately upon graduation. While excellent for its intended purpose of scientific 'discovery', investigation and 'inquiry', the National Collaborative Task Force concludes that traditional research-oriented M.S. and Ph.D. graduate education ***does not meet*** the full professional spectrum of educational needs or reflect the 'engineering method' of creative engineering practice for the majority of the nation's engineers, who are ***not*** pursuing research-oriented careers, but rather as creative practitioners, are pursuing the creative practice of engineering in industry for technology development and innovation.

For these engineers, a different approach and educational process is needed, which better supports lifelong learning and the modern paradigm of the practice of engineering for creative technology development and innovation throughout their professional careers. As the 1974 National Science Foundation report [*Workshop on Continuing Education for Engineers at Mid-Career*] pointed out ─ "Coursework has ***not*** been designed which correlates well with the professional growth of engineers, either as technical specialists or as managers … Selection of educational experiences generally relies on the individual engineer's selection from a 'cafeteria' of study opportunities."[22] It is now time to make this needed correction to better develop the necessary engineering skill-sets for our nation's domestic talent for indigenous technological innovation.

3. Plan of Action

3.1 The Engaged University ─ Building Upon Existing Strengths of Universities and Industry Across the Nation

The call for reform of U.S. engineering education more relevant to the modern practice of engineering for systematic technology development and innovation, and to the professional needs of graduate engineers pursuing innovative careers in engineering practice in industry through the professional Master of Engineering and professional Doctor of Engineering levels, has been made for several years.

Since the Kellogg Commission Reports, there is widespread awareness that universities must change and become more engaged with their constituencies.[23] This initiative is an outgrowth of that recognition. Much work has already been done across the nation to accelerate this reform. In particular, the landmark works of Conrad and Haworth [sponsored by the Council of Graduate Schools] sets the stage in identifying the educational attributes that contribute to excellence in professional education for working professionals in industry.[24, 25] Much of this work is applicable and can be extended to both professional master's and to professional doctoral education for advanced practitioners in engineering.

3.2 Strategic Plan for Action

To meet the challenge, the National Collaborative Task Force has embarked upon the complex task of developing and implementing an educationally sound and cost-effective approach of innovative professional graduate education for the nation's graduate engineers as a complement to research. This approach shows great promise and has the potential to be a major player in developing engineering leaders across all regions of the nation who are so desperately needed in developing the new needed technologies to help the nation recover economically and regain its competitive edge.

Our priorities for action include the following tasks:

PHASE I: Definition Phase

Task #1: Define Progressive Growth Levels of Engineering Beyond Entry [I – IX]

Assess the progressive stages of growth and levels of increasing responsibility in the practice of engineering for leadership of responsible technology development and innovation in industry[14].

Task #2: Identify Core Progressive Skill-Sets in Engineering for all Levels

Identify the professional skill-sets, experience factor, and knowledge required at all growth levels for engineering-leadership of technology development and innovation

a) Early-career Level I – III Engineer

b) Mid-career Level IV–VI Engineer

c) Senior-career Level VII–IX Engineer

Task #3: Integrative Framework of Professional Graduate Education and Practice

Define a coherent and integrative framework of high-quality, postgraduate professional engineering education that is combined with the graduate's on-going practice of engineering for creative technology development and innovation in industry leading to:

a) the professional Master of Engineering (M.Eng.) at Level III Engineer[26] [Appendix B-1]

b) the professional Doctor of Engineering (D.Eng.) At Level VI Engineer[27] [Appendix B-2]

PHASE II: Curricular Development Phase

Task #4: Define and Align Professional Curricula to Support Progressive Skill-Sets

Define and align relevant professional curricula that match and support the progressive skill-sets, required of graduate engineers for engineering leadership of technology development and innovation from:

a) Early-career Level I – III Engineer

b) Mid-career Level IV –VI Engineer

c) Senior-career Level VII – IX Engineer

Task #5: Professional Course and Module Development

Develop core professional course materials, modules, seminars, independent studies, and provision for electives required to support coherent postgraduate professional engineering programs through:

a) the professional Master of Engineering (M.Eng.) at Level III Engineer

b) the professional Doctor of Engineering (D.Eng.) at Level VI Engineer

PHASE III: Organizational Development Phase

Task #6: Faculty Recruitment and Development

a) Recruit Distinguished Experience Faculty

Identify and recruit a core cadre of experienced faculty from within the university combined with a core cadre of experienced, distinguished adjunct faculty from regional industry or government service who are capable to teach and help other experienced graduates learn in this mode of postgraduate professional education

b) Develop Faculty

Develop faculty through teaching workshops focused on attributes that enable experienced practicing professionals to further learn, grow, and develop to the next levels of excellence in practice [Conrad and Haworth]

Task #7: Recruitment of Graduate Practitioner Students in Industry

Recruit qualified, experienced graduate engineers within regional industry and government service who are qualified, capable, and want to continue their professional growth in the practice of engineering for responsible leadership of effective technology development and innovation relevant to their organization's or societal needs

PHASE IV: Implementation Phase

Task #8: Establish Regional Graduate Centers

Establish 5 – 10 high-quality Graduate Centers (Institutes) of Advanced Studies for Engineering Leadership of Technology Innovation in different states across the nation

Task #9: Roll-Out and Start-Up Operations

Roll-out and start-up of operations of 5 – 10 new high-quality programs of professional graduate engineering education for regional graduate engineers in partnership with regional industry for pilot demonstration, and replication across the United States

Task #10: Continuous Improvement and Replication

Define mechanism to periodically assess needs of regional graduate engineers / industry for further development of a relevant dynamic professional curriculum for sustainable growth

4. Impact: Benefits to Universities, Industry, Graduates, and the Nation

The potential impact of strengthening America's industrial infrastructure for enhanced U.S. engineering innovation and technological competitiveness will yield significant impact to universities, industry, graduate engineers, and the nation's competitiveness across all regions of the United States over both the immediate and long terms.

4.1 What's In It for America's Industry?

- Small, medium-sized and large scale industry all benefit through increased competitiveness by further developing their engineering talent through advanced professional education for innovative works.
    - improving product design and development
    - improving their manufacturing process
    - reducing operating costs
    - improving quality
    - finding new markets
    - increasing sales
- The initiative provides a very unique postgraduate opportunity that further develops industry's graduate engineers as emerging leaders and 'champion' for technological innovation while creating, developing, and innovating new needed engineering innovations simultaneously through solutions of particular technical challenges performed concurrently as deliberate outcomes of the graduate practitioner's advanced studies and engineering project work.
- Based on the initial experiences of the Task Force members, the average benefits that a company can expect in return from the creative engineering projects is a value added worth in excess of $200,000 which often is a reoccurring annual benefit.
- The initiative provides opportunity for closer access and more effective engagement to the knowledge base and expertise of high quality engineering faculty at regional universities across the nation.
- The initiative provides a very cost-effective mechanism for companies to access high-quality postgraduate professional education that furthers the advanced progressive growth of more of their graduate engineers without loss of their continuity, growth and creative productivity on the job, and uprooting of families and added expense of sending these employees to more distant universities.

4.2 What's In It for America's Universities?

- The initiative is worth millions to participating U.S. universities across all regions of the nation.
  - increases graduate enrollments
  - increases tuition revenues
  - increases engagement with industry
  - increases opportunity for industrial research sponsorship

- The initiative provides opportunity for industrial endowments and distinguished industrial advisory councils providing sound guidance for sustainable program success.

- Enhances close industry-university collaboration in attracting America's creative talent to enter the undergraduate talent pipeline and then have the opportunity to pursue further advanced professional graduate education, while fully employed, for long-lasting innovative careers in industry or mission-oriented government service.

- Increases the teaching relevance of the university engineering faculty through closer engagement with regional industry and the practicing profession for both the basic undergraduate level and for the advanced level of professional graduate engineering education.

- Provides participating collaborative universities a very cost-effective mechanism to add distinguished, experienced faculty from industry of world-class expertise in engineering and innovation to teach others.

- Provides participating universities a very cost-effective mechanism to raise their overall engineering knowledge base, professional expertise, and prestige within their university missions for professional education to world-class preeminence, as a complement to their research missions, across all regions of the United States.

4.3 What's in it for the Nation's Graduate Engineers?

- Enhances career growth and prospects of graduates throughout their entire professional careers of creative engineering practice and leadership of innovation in industry.

- Enables a coherent educational opportunity for continued growth and professional development of the graduate engineer, beyond entry-level, through the early-career stages of an engineer's professional development to attain the professional Master of Engineering degree developing the leadership skill-sets required at Level 3 Engineering.

- Enables a coherent educational opportunity for continued growth and professional development of the graduate engineer, beyond the professional Master's, through the mid-career stages of an engineer's professional development to attain the professional Doctor of Engineering degree developing the leadership skill-sets required at Level 6 Engineering.

- By providing coherent opportunity for lifelong learning, growth and development that is integrated concurrently with on-going engineering practice, in partnership with regional universities, the initiative has the potential to uplift the competency and proficiency of the practicing profession of engineering across all regions of the nation.

- Graduates benefit from:
  - Improving engineering skills in professional work functions
  - Gaining qualifications that demonstrate they are competent engineers and engineering leaders
  - Gaining insight into best practice of technology development and innovation
  - Gaining insight into business practice, systems approach thinking, project engineering, technology program making, technology policy making, and effective decision making for industrial growth
  - Engaging in original engineering development directed towards clear industrial objectives

4.4 What's in it for the Good of the Nation?

- Unlocks the creativity, inventiveness, leadership and innovative potential of the U.S. engineering workforce in industry across all regions of the United States for world-class competitiveness in technology development and innovation.

- Increases U.S. technological competitiveness by strengthening local and regional engineering innovation in industry across the country as a primary source of the nation's competitiveness.

- Develops a strong continuity for the development and progression of engineering talent for leadership roles in America's industry.

- Provides an effective world-class mechanism for accelerating the generation, development, and innovation of new, improved, and breakthrough technology through regional graduate centers for advanced professional graduate education that integrate advanced studies, relevant engineering projects, with the engineers experience and on-going creative engineering work in industry:

  - Estimate 100 – 300 graduate-engineer practitioners engaging in advanced studies and relevant engineering development projects in industry per industry-university regional graduate center.

  - Estimate 100 – 300 projects @ $200,000 value added per project = $20 – $60 Million value added to regional industry per regional industry-university graduate center per annum.

  - Estimate initial build up of 10 graduate centers over five years in different states = 1000 to 3000 graduate engineers undergoing advanced studies focused on innovation and engineering leadership development for U.S. competitiveness.

- Estimate 10 graduate centers @ $20 – $60 Million value added per center = $200 – $600 Million value added return to participating industries across the country per annum and the expected creation of new jobs to the economy.

- With the ultimate expansion of the National Demonstration Project to all 50 graduate centers [at least 1 center in each state] 50 @ $200 – $600 Million value added per center = $10 – $30 Billion value added return to participating industries across all states per annum with the expected creation of new jobs and new needed technologies contributing to U.S. competitive advantage.

- The further expansion of the initiative to all 50 states will engage a minimum of at least 5,000 – 15,000 engineering graduates in further postgraduate professional education. These estimates are very conservative.

- Using an ASEE estimate of 73,000 newly minted engineers graduating per year [2008], this initiative has the potential to foster high-quality opportunity for at least 10% - 20 % of the nation's recent graduate engineers to participate in this new approach and to continue their postgraduate professional graduate education for sustained innovative engineering careers in industry or mission-oriented government service. The Task Force believes that bringing more relevancy to the context and process of postgraduate professional education, specifically designed to meet the growth needs of America's practicing professionals, will encourage more of the nation's engineers to take their rightful place in graduate engineering education, which is now populated primarily by foreign nationals.

5. Conclusions and Next Steps ─ Investing in Our Future through U.S. Engineering

There is no doubt that we are now in a new era requiring America to rebuild its industrial base and sustain its technological strength. Today, as never before, America's competitiveness depends on continuous innovation by graduate engineers working in industry. Their ideas are the primary, creative well-spring of U.S. technological development and innovation.

5.1 Strengthening U.S. Competitiveness

As Elkus points out: "Competitiveness shapes the fate of nations" … and … "a nation's competitive position will ultimately be reflected in its system of education."[28] This statement underpins the National Collaborative rationale in developing a more relevant U.S. system of postgraduate professional education that better supports the further development of the nation's graduate engineers in America's industry for world-class innovation in the global economy.

The National Collaborative initiative is a call to action to better develop the engineering professionals of the future who are needed to stimulate and lead the continuous technological innovation process in industry to sustain U.S. competitiveness. Toward this aim, a new alliance has been formed among a pilot alliance of innovative universities across the United States in partnership with U.S. industry to address the needed transformation in reshaping professionally oriented engineering graduate education and establishing the conditions required for innovation to flourish within America's industry.

5.2 Toward a New Partnership for America's Future

Today, federal government must partner in the transformative process of educational change and provide adequate financial resources and the environment for this collaboration to occur. Precedent has already been set by federal government to rightfully partner in improving graduate education for professional science degrees, which has been endorsed by the Council of Graduate Schools,[29] the National Research Council,[30] and endorsed in the America Competes Act in a bipartisan manner. It is now timely to parallel this improvement in professional graduate education for engineering which this initiative addresses.

The National Collaborative initiative is a continuous work in progress that is making headway. But the proposed changes will not happen overnight. The importance of this major educational initiative to strengthen U.S. engineering capacity for economic recovery and competitiveness in the global economy has far reaching implications. The central themes of the initiative are twofold:

a) First, the nation's future economic prosperity, technological competitiveness, and national security require continuous engineering progress for new technological developments in America's industry. Creative technological developments are at the heart of rebuilding America's competitiveness and creating jobs. At the heart of creative technological developments are creative engineers in industry. Ultimately the future technological capability of the U.S. depends on the supply and professional education of well-qualified engineers, so the further postgraduate professional education of our nation's creative engineering talent must become a national priority.

b) Second, supportive of the professional education of the nation's engineers, who create and bring forth these new technological developments and innovations, must be a new type of world-class postgraduate professional education, specifically designed to foster coherent professional development throughout the graduate's entire creative professional career, while fully employed in engineering practice in industry, enabling continuous growth of the graduate through the professional master's and professional doctoral levels of engineering in a manner concurrent with practice.

5.3 Implications for Universities and U.S. Industry

At regional university-industry graduate centers, established by the National Collaborative, graduate engineers employed in regional industry around the country will be able to enhance their innovative capacity, leadership competence and creativity. Using a combination of distance and on-site learning, and actual creative project-based learning in industry, these regional graduate centers will enable the engineering workforce in the surrounding industrial areas to further develop the professional knowledge and abilities required of engineers for responsible leadership of technology development and innovation, and, simultaneously, develop innovative new technology in industry.

The nine levels of progressive professional skill-sets, required of graduate engineers from entry level through the chief engineer level, will serve as specifications for new curricular development for professional master's and professional doctoral programs. The new professional curricula will enable the graduate-practitioners of these postgraduate programs to attain both engineering knowledge and practical workplace skills that can contribute significantly to U.S. competitiveness through the productive outcomes of their creative engineering works. The concept has the potential to yield multifaceted returns worth millions to participating universities through increased tuition revenues and increased industrial engagement, and to participating industry across all regions of the United States through increased U.S. competitiveness by the innovations produced by these graduate engineer employees who are emerging as responsible leaders nurtured by advanced professional education and application of their enhanced skill-sets on the job.

5.4 Recommendations

The National Collaborative has gained widespread support, based on the impact that will be felt in every state from enhancing the innovative capacity of the regional industrial engineering workforce for enhanced competitiveness. Partnering professionally oriented graduate education with the practicing engineering profession in America's industry will stimulate significant regional innovation, new technology developments and economic growth across the country. Investment in the National Collaborative initiative is an investment in the long-term educational development of our nation's infrastructure for continuous engineering innovation in industry.

Because the core professional curricula support the commonality of professional skill-sets required in the practice of engineering, this investment has the potential to benefit all forms of technology-based industry across the United States. As Gomory and Baumol have reflected: "Government outlays on infrastructure such as roads or an advanced educational system are not aimed at particular industries but benefit many."[31] This initiative can contribute significantly to America's economic recovery and in stimulating the generation and development of new needed technologies through a strengthened engineering infrastructure for innovation.

Thus, it is the recommendation of the National Collaborative Task Force that federal government should invest in this initiative which is educationally sound, innovative, and attainable across all regions of the country. This initiative has the potential to yield significant returns having profound and multifaceted impact in the nation's economic recovery and competitiveness by stimulating the creativeness, inventiveness, and innovative capacity of the U.S. engineering workforce in America's industry, second to none. It is an investment worth doing, with far reaching effects that will last throughout the 21st century in raising America's engineering base in industry to the next level for world-class competitiveness. The initiative is within the mission of professional education of the modern 21st century university engaged with the practicing profession. This is a minuscule investment in terms of the national budget with enormous positive returns to the nation's competitiveness and enhancement of U.S. innovative capacity required for long-term economic prosperity, national security, and improvement in our quality of life.

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Appendix A

Guidelines for Engineering Education Reform to Develop Professionally Oriented Graduate Education to Enhance the Innovative Capacity of the

U.S. Engineering Workforce in industry

GUIDELINES FOR NATIONAL COLLABORATIVE TASK FORCE

- Focus on innovation and leadership
- Focus on development of U.S. Engineering Workforce for innovative competitiveness in industry, second to none in the world
- Vision ─

  "Innovation fosters the new ideas, technologies, and processes that lead to better jobs, higher wages and a higher standard of living. For advanced industrial nations no longer able to compete on cost, the capacity to innovate is the most critical element in sustaining competitiveness."

  Council on Competitiveness
- Workforce Development ─

  "The Council's business leaders agree that every company's most important asset are the people who walk in its doors every morning. Talented people creating new ideas and innovative technologies keep the economy strong, and growing stronger. The education and training that spark Americans' creativity and give them cutting-edge skills are a key to competitiveness.

  Council on Competitiveness
- Create a new, innovative professional curriculum combined with engineering practice that matches and supports the progressive core-competence skills required for effective engineering leadership of technology development & innovation in industry ─ from beginning Entry Level Engineer through the Chief Engineer / Vice President of Engineering and Technology level for corporate technology responsibility
- Graduate centers that will be "statewide clusters" for advanced professional education for engineering innovation and leadership in all 50 states across the nation
- Use the combined formidable teaching and human resource strengths of regional universities and industry in this process

- Form a unique collaborative partnership between industry and universities in developing the creative and innovative capacity of the U.S. Engineering Workforce in industry for world-preeminence in technology development and innovation

- Enable and encourage "lifelong learning" within the engineering population of a company to stimulate innovation

Appendix: B-1

Suggested Aims of Professional Master of Engineering (M. Eng.)

Programs for Practicing Professionals in Industry

Professional Master of Engineering ─ For Creative Engineering Practice and Leadership Level III Engineer –Skill-Sets / Outcomes

- ***Aims of professional Master of Engineering programs for engineering practice and leadership***

  a) Professional Master of Engineering (M.Eng.) programs provide a very practical component to lifelong learning; a recognized professional degree; and an integrated approach that combines advanced studies with self-directed learning, progressive experience in engineering practice, and actual engagement in creative technology development and innovation.

  b) High-quality, postgraduate professional M.Eng. programs should emphasize project-based (problem-centered) ─ "innovation-based learning" ─ concurrent with creative engineering practice thereby enhancing work-related professional skill-sets required for progressive levels of attainment from entry-level to Engineer III level proficiency.

  c) Professional M.Eng. programs should support the skill-sets/outcomes required for responsible leadership of significant work at Engineer III level of project engineering leadership responsibility.

  d) Professional M.Eng. programs should recognize postgraduate education not only as a learning process beyond the baccalaureate, but as a process for continuous professional development of intrinsic human potential, for further development of creativity, innovation, and leadership wherein self-directed learning, progressive experience, tangible project-based learning, and further advanced studies all serve as integral components of a working professional's lifelong growth process to reach his or her potential for responsible leadership in engineering practice.

  e) Professional M.Eng. programs should be specifically designed to be concurrent with and to support the working professional's on-going creative work and stage of growth in engineering practice for responsible leadership of creative, systematic technology development and innovation.

  f) Residency should be viewed as residency in engineering practice in the professional's workplace in industry/government service. Postgraduate professional M.Eng. programs enable the working professional to continuously learn, grow, and develop while he or she is fully employed without disrupting the practitioner's normal work activities or uprooting home, family, or career to continue high-quality professional education in engineering practice.

- ***Target market for professional Master of Engineering programs***

  a) The professional master's programs in engineering practice and technology leadership should be targeted to enhance the innovative capability of graduate engineers within the U.S. Engineering Workforce (in regional industry across the nation) who are actively engaged in innovative technology development and continuous improvement at project engineering leadership level of responsibility.

  b) The professional M.Eng. programs should be specifically designed to continue the professional education of graduate engineers, after entry into industry, who are emerging as leaders and are pursuing career paths that are not centered on research but are centered on the purposeful, systematic engineering creation, development and innovation of new/improved technology in the form of new/improved/breakthrough products, processes, systems, or technical operations.

- ***Integrative professional curriculum with engineering practice***

a) Whereas, basic undergraduate engineering education prepares young, inexperienced engineers for entry into engineering practice and is predominantly based on a faculty-centered, content-model of instruction focusing on the transmission of knowledge from teacher to student for postponed application, the intent of advanced professional engineering education is to further the continued professional development of experienced engineers beyond entry-level toward their fullest potentials as creative professionals and responsible leaders at the highest levels of leadership responsibility in engineering practice.

b) As such, high-quality professional education should shift from a traditional faculty-centered, content-model of instruction to a learner-centered, process-oriented model of continuous professional development focusing on further development of the working professional's intrinsic creative, innovative, and leadership potential for increasing self-directedness, inventiveness, and engineering leadership skills for immediacy of application in actual creative engineering work.

c) Professional education should be practice-oriented and designed from a holistic approach that more fully develops the engineer's breadth and depth in the context of actual engineering practice for leadership of on-going technology development and innovation projects.

d) Professional education for engineers should shift from the traditional perspective of one-time learning to a process of continuous professional development that builds upon the accumulated wealth of the working professional's progressive experience; an already established technical knowledge base; and an already established skill-sets base and competency base in his or her field of technology.

e) Professional M.Eng. programs for working professionals should be specifically designed to build upon six major integrative ingredients. These include:

   (1) Knowledge and skill-sets acquired by undergraduate education in engineering [ABET].
   (2) The engineer's already established competency base in a technological field in industry.
   (3) On-going experiential-based learning in creative engineering practice.
   (4) Self-directed learning necessary to gain technological expertise in the practitioner's field.
   (5) Project-based learning in substantive technology development project work.
   (6) Planned professional core studies and electives concurrent with practice.

- ***Scope of technology projects and expected project outcomes and impact***

a) Technology development projects should be specifically selected to be directly relevant to significant needs of the participant's sponsoring industry/or of society; and should be selected by the participant with the approval of an oversight committee from industry and the university.

b) Technology development projects should provide the participant a meaningful professional learning experience at Engineer III level of project engineering leadership responsibility and result in substantial improvements in products, processes, systems, or operations to the graduate participant's sponsoring industry.

c) Technology projects should yield new "ideas and concepts" for creative engineering solutions through proof of feasibility for new technological improvements, developments, and innovations for products, processes, systems, and technical operations or organizational infrastructure that ultimately contribute to the body of new technological knowledge of benefit to the advancement of engineering practice, the graduate participant's corporate sponsor, and society as a result of this deliberate creative engineering work for constant engineering innovation.

d) Technology development projects should result in a project report and a quality tangible experience of meaningful significance that is directly relevant to the technology development and innovation needs of the graduate participant's sponsoring industry/or society. This work should represent deliberate creation, improvement, development and innovation at the project engineering leadership level wherein the graduate participant is in responsible charge.

- ***Expectations of skill-sets / outcomes for participant Engineer-Leaders***

a) The professional master's program should be a two-year postgraduate program, which is integrated concurrently with engineering practice, that is project-based and is specifically designed to foster the professional growth of experienced working professionals beyond entry-level in industry/government service on a continuous basis while they are fully employed. The program should be designed to nurture the engineer's leadership of technology development and innovation by combining advanced studies with engineering practice in a synergistic fashion.

b) The program should be designed to meet the progressive skill-sets of creative engineering practice for ABET graduates (engineering/engineering technology) who are assuming career paths and responsible leadership roles in engineering practice for technology development and innovation relevant to their corporate engineering mission. The program should be designed to further the growth of experienced engineers for progressive levels of attainment as full-fledged practitioners, systems developers, innovators, integrators, and leaders for responsible charge of meaningful engineering project work.

c) The program should be designed to foster the continuous professional development of Engineer-Leaders who contribute to the creation, improvement, development, and innovation of new technology-based systems, operations, products, and processes on which regional industrial growth and economic development depends for creation of new wealth/employment/national security purposes.

d) The program should be designed for those engineers who can make original contributions to the creation, invention, and development of new/improved technology through purposeful, systematic improvement/breakthrough innovation. And as a result of their creative engineering work, add to the body of new technological knowledge as leaders for the region's and nation's technological progress and competitiveness.

e) Participants are expected to emerge from the professional master's program as fully competent professionals and experienced Engineer-Leaders in a functional area of the sponsor's technology with the skill-sets, knowledge, experience, and outcomes ready to assume responsibilities associated with Engineer III qualifications for technology project leadership.

- ***Entrance requirements***

a) High-quality postgraduate professional master's programs should be formulated to enable working professionals to enter them at an early career stage in engineering practice/and at later stages of professional development when the additional learning and growth experience would be most valuable. It is now understood that the integrative combination of practical engineering experience plus further advanced studies is a valuable component of an engineer's continuing professional education beyond the baccalaureate.

b) Because many of the skill-sets that are required during the professional maturation process in engineering practice for leadership of technology development and innovation in industry can only be attained through practical experience, it is recommended that a minimum of at least six months of professional experience in engineering practice, beyond a four-year undergraduate education in engineering/engineering technology from an ABET accredited institution, should be required for entrance into these professionally-oriented graduate programs. Completion of the FE for progression toward licensure is also recommended when appropriate.

Appendix: B-2

Suggested Aims of Professional Doctor of Engineering (D. Eng.) Programs for Practicing Professionals in Industry

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Professional Doctor of Engineering ─ For Creative Engineering Practice and Leadership Level VI Engineer – Skill-Sets / Outcomes

- ***Aims of professional Doctor of Engineering programs for engineering practice and leadership***

  a) Professional Doctor of Engineering (D.Eng.) programs provide a professional alternative to research-based PhD programs for engineers engaged in needs-driven technology development and innovation in industry and a coherent component of lifelong learning for continuous professional development in creative engineering practice beyond the professional M.Eng.

  b) Professional D.Eng. programs for engineering practice and technology leadership should be specifically designed to be integrative with and in the context of on-going engineering practice for leadership of technology development and innovation in industry and should emphasize project-based (problem-centered) ─ "innovation-based learning" ─ concurrent with practice.

  c) Professional D.Eng. programs should support the skill-sets required for responsible leadership of significant work at Engineer VI level of technical program and technology policy responsibility.

  d) Professional D.Eng. programs should recognize postgraduate education not only as a continuous learning process beyond the master's, but as a process for continuous professional development of intrinsic human potential for further development of creativity, innovation, and leadership wherein self-directed learning, progressive experience, tangible project-based learning, and further advanced studies all serve as integral components of a working professional's lifelong growth process to reach his or her potential for leadership in engineering practice.

  e) Professional D.Eng. programs should be specifically designed to be concurrent with and to support the working professional's on-going creative work and stage of growth in engineering practice for responsible leadership of creative, systematic technology development and innovation.

  f) Residency should be viewed as residency in engineering practice in the professional's workplace in industry/government service. Postgraduate professional D.Eng. programs enable the working professional to continuously learn, grow, and develop while he or she is fully employed without disrupting the graduate practitioner's normal work activities or uprooting home, family, or career to continue high-quality professional education in engineering practice.

- ***Target market for professional Doctor of Engineering programs***

  a) Professional doctoral programs for responsible technology leadership in engineering practice should be targeted to enhance the innovative capability of engineers within the U.S. Engineering Workforce (in regional industry) who are pursuing career paths that are not centered on research but are centered on the purposeful, systematic engineering creation, development and innovation of new/improved technology in the form of processes, systems, or technical operations.

b) Professional D.Eng. programs should be specifically designed to continue the professional education of graduate engineers, after entry into industry, who have at least 5 to 10 years of progressive experience beyond entry-level, hold the professional M.Eng. (or equivalent), and are actively engaged in responsible leadership of innovative technology development in industry/government service.

- ***Integrative professional curriculum with practice***

a) Whereas traditional graduate scientific education and research-oriented PhD programs are purposefully designed to prepare traditional graduate students as future academic researchers and independent scientific investigators in the context of on-going scientific research investigations — and emphasize inquiry-based learning for scientific "discovery" — the intent of the professional D.Eng. program is to further the professional development of experienced engineers beyond the professional M.Eng. level toward their fullest potentials for creativity, innovation, and leadership for needs-driven technology development and innovation in engineering practice in industry.

b) High-quality professional D.Eng. programs, designed for technology development engineers, should shift from emphasis on inquiry-based learning for scientific "discovery" to purposeful, creative problem solving and engineering innovation driven by real-world human needs; and should be designed in the context of advanced engineering practice to emphasize project-based (problem-centered) — "innovation-based learning "— concurrent with engineering practice.

c) Professional curriculum for the D.Eng. should be practice-oriented and designed from a holistic approach that more fully develops the engineer's breadth and depth in the context of engineering practice for leadership of on-going technology development and innovation projects.

d) Professional education should shift from the traditional perspective of one-time learning to a process of continuous professional development that builds upon the growing wealth of the working professional's progressive experience, expertise, and an already established technical knowledge base and skill-sets base in his or her field of technology. Emphasis should shift from classroom instruction to increasing self-directedness and leadership of technology development.

e) Professional D.Eng. programs should be specifically designed to be concurrent with engineering practice and should build upon six major integrative ingredients. These include:

(1) Knowledge and skill-sets acquired by undergraduate and master's education in engineering.
(2) The engineer's already established competency base in a technological field in industry.
(3) On-going experiential-based learning in creative engineering practice.
(4) Self-directed learning necessary to gain technological expertise in the practitioner's field.
(5) Project-based learning in substantive technology development project work.
(6) Planned professional core studies and electives concurrent with practice.

- ***Scope of technology projects and expected project outcomes and impact***

a) Technology development projects should be specifically selected to be directly relevant to significant needs of the participant's sponsoring industry/or of society; and should be selected by the participant with the approval of an oversight committee from industry and the university.

b) Technology development projects are selected to provide the participant a meaningful professional learning experience at Engineer VI level for technical program responsibility and are expected to result in substantial improvements/breakthroughs in products, processes, systems, or operations to the participant's sponsoring industry.

c) Technology projects should yield new "ideas and concepts" for creative engineering solutions through proof of feasibility for new technological improvements, developments, and innovations for products, processes, systems, and technical operations or organizational infrastructure that ultimately contribute to the body of new technological knowledge of benefit to the advancement of engineering practice, the participant's corporate sponsor, and society as a result of this deliberate creative engineering work for constant innovation.

d) Technology development projects will be of a directed nature resulting in a project report and a quality tangible experience of meaningful significance that is directly relevant to the technology development and innovation needs of the participant's sponsoring industry/ or society. This professional work should represent creation, improvement, development and innovation at the technical program leadership level wherein the participant is in responsible charge.

- ***Expectations of skill-sets / outcomes for participant Engineer-Leaders***

a) The professional D.Eng. program should be a two-year postgraduate program beyond the professional M.Eng. that is project-based and is specifically designed to foster the professional growth of senior Engineer-Leaders while they are fully employed in industry/government service. The program should be designed to nurture the engineer's leadership of technology development and innovation by combining advanced studies with engineering practice in a synergistic fashion.

b) The D.Eng. program should be designed to meet the progressive skill-sets of creative engineering practice for senior Engineer-Leaders who are engaged in career paths of responsible leadership in engineering practice for technology development and innovation relevant to their corporate engineering mission. The program should be designed to further the growth of senior engineers for progressive levels of attainment as full-fledged practitioners, systems developers, innovators, integrators leaders for responsible leadership charge of meaningful technology programs.

c) The D.Eng. program should be designed to foster the continuous professional development of Engineer-Leaders who lead the systematic creation, improvement, development, and innovation of new/improved technology for products, processes, systems, or operations on which regional industrial growth and economic development depends for creation of new wealth, employment, or for national security purposes.

d) The professional D.Eng. program should be designed for those senior engineers who can make original contributions through their leadership of systematic technology development for constant innovation and as a resulting outcome of their creative leadership add to the body of technological knowledge as responsible leaders of the region's and nation's technological progress for competitiveness.

e) Graduate participants are expected to emerge from the professional D.Eng. program as fully competent professionals and experienced Engineer-Leaders in a functional area of the sponsor's technology with the skill-sets, knowledge, experience, and outcomes ready to assume responsibilities associated with Engineer VI qualifications for leadership of significant technology programs and policy.

- ***Entrance requirements***

a) High-quality postgraduate professional D.Eng. programs should be formulated to enable working professionals to enter them at a career stage of professional development in engineering practice when the additional learning and growth experience would be most valuable. It is now understood that the integrative combination of progressive practical engineering experience plus further advanced studies is a valuable component of an engineer's continuing professional education beyond the professional master's.

b) Because many of the skill-sets that are required during the professional maturation process in engineering practice for senior leadership of technology development and innovation in industry can only be attained through progressive practical experience, it is recommended that a minimum of at least five to ten years of progressive professional experience in engineering practice, beyond entry-level, plus the professional M.Eng. should be required for entrance into these professionally-oriented graduate programs. Completion of the PE is also recommended when appropriate.