2006-421: ENABLING A STRONG U.S. ENGINEERING WORKFORCE FOR LEADERSHIP OF TECHNOLOGY DEVELOPMENT AND INNOVATION IN INDUSTRY: SETTING A NEW VISION FOR INTEGRATIVE PROFESSIONAL GRADUATE EDUCATION IN ENGINEERING PRACTICE

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Enabling a Strong U.S. Engineering Workforce for Leadership of Technology Development and Innovation in Industry: Setting a New Vision for Integrative Professional Graduate Education in Engineering Practice

1. Introduction

This is the first of four papers prepared for a special panel session of the National Collaborative Task Force on Engineering Graduate Education Reform that is focusing on the deliberate advancement of professional engineering graduate education to enhance the innovative capacity of the U.S. engineering workforce in industry for global competitiveness. Founded in 2000, the National Collaborative Task Force is an initiative of the ASEE-Graduate Studies Division, Corporate Members Council, and College Industry Partnership Division. The National Collaborative is comprised of leaders from industry, academia, and government all coming together to advance engineering education for the practice of engineering in the national interest.

This paper reports on the progress that the National Collaborative is making and it describes the transformation required in engineering education mandated by the new paradigm that has occurred in the practice of engineering for creating, developing, and innovating new, improved, and breakthrough technology as a systematic practice. The reform necessitates a new type of professionally oriented engineering education at the graduate level that better develops the innovative capacity of the U.S. engineering workforce in industry for competitiveness and that better supports the innovation skills required of engineers at all levels of leadership responsibility for technology innovation.

2. The New Economy ─ The Importance of Engineering to U.S. Competitiveness

During the 20th century, America built its engineering preeminence and technological infrastructure for both civilian needs and defense purposes on its world-class capability for creative engineering practice in industry and mission oriented government service. Industry's core engineering competence for creative technology development and innovation has been supported by a system of engineering education envied by other countries. But during the last decades a noticeable decline in U.S. technological competitiveness began to emerge that is now being correlated in part with challenges by other nations and with how we educate U.S. engineers at the graduate level for the professional practice of engineering in industry.

2.1 Challenges to U.S. Technological Leadership

As the United States competes in the 21st century, it is facing new strategic environments for innovation. America is being challenged today as never before. Other nations are investing heavily in the development of their engineering workforce as a key ingredient to their success. As a consequence, the importance of developing the U.S. engineering workforce in industry is becoming a national priority to accelerate America's thrust for technological innovation.

As the Council on Competitiveness points out, [1]

> "The United States now finds itself at a potential inflection point — facing new realities that pose significant challenges to our global innovation leadership. … China now graduates four times the number of first university engineering degrees than does the U.S. Moreover, the number of young people earning S&E degrees is growing faster in the U.K., France, Japan, Canada, and Germany than in the U.S…. The United States share of its own industrial patents has fallen steadily over the decades and now stands at only 52 percent."

2.2 A New Strategic Environment: Challenging U.S. Technological Leadership

As the Center for Strategic and International Studies points out, a new strategic environment challenging U.S. technological leadership has emerged:[2]

- "The last fifteen years has seen, the emergence of a strategic environment very different from what many Americans expected at the end of the Cold War … The United States has gone from leading an alliance of Western democracies in a global defense against a superpower foe to a world where alliances are less cohesive and threats are more diffuse … The long term strategic challenge lies with the emergence of powerful new states."

- "Strategic competition is an indirect kind of national competition that occurs over the long term … The U.S. goal is not to prevent competition from growing, but to ensure that America grows as fast as or faster than they do. The U.S. needs foreign policies that encourage others to grow, but it must match these with domestic policies that maintain U.S. leadership … From a macro perspective, however, this strategic competition holds a much greater potential to affect the U.S. national interest and security … The long term result is that nations compete by seeking to surpass the U.S. economically and technologically."

- "The new competitors include nations, among them China, who see themselves now or in the future as challenging the U.S. for economic power, international influence and regional or global leadership … Their motives for competition are a combination of a desire for economic growth and a reactive response to assert their national interests in the face of U.S. leadership … The U.S. is the benchmark by which other nations define their growth and success. The flow of international politics, driven by displeasure, concern or envy for a perceived U.S. preponderance, creates nationalistic motives that drive efforts at development. The dangers of terrorism and the short-term focus of politics and business make it easy to overlook this, but the real competition for the U.S. lies in this race for economic growth and technological leadership."

- "In some cases, such as with China or in Europe, there are explicitly stated goals to diminish U.S. influence in global affairs. Many Europeans hope to see the EU emerge as an economic superpower that will counterbalance the U.S. military 'hyperpower.' While aspects of the transatlantic relationship remain strong, Europe can often only define itself through contrast and competition with the United States. Chinese leaders make no secret of their desire to displace the U.S. in Asia."

3. Task Force Findings

As a result of its study phase, the National Collaborative Task Force on Engineering Graduate Education Reform has identified five major findings that it believes are critically important in accelerating America's engineering capacity to innovate.

Finding 1: America Must Innovate: Tapping U.S. Engineering Potential in Industry

Tapping America's engineering potential in industry must become a national priority for innovation. No longer can America compete globally on labor costs. America must retain its engineering preeminence for innovation through workforce development to accelerate U.S. technological leadership for competitiveness and national security purposes.

To compete, as a nation, we must create (invent), develop, and innovate new, improved, and breakthrough technology in industry ***in the form*** of more affordable and better products, processes, systems and operations through creative engineering practice. And, we must do so on a continuous basis to meet the hopes, wants, and needs of people domestically and globally.

As the Council on Competitiveness points out:

- "Innovation will be the single most important factor in determining America's success through the 21st century."
- "Innovation *fosters the new ideas, technologies, and processes that lead to better jobs, higher wages and a higher standard of living*."

Finding 2: U.S. Technology Competitiveness Occurs Primarily in Industry

As Michael Porter has pointed out, "A nation's competitiveness depends on the capacity of its industry to innovate and upgrade." [3] Moreover as Porter notes, "Future U.S. competitiveness will hinge on the capacity to foster clusters of innovation in cities and all regions across the country where industries are based, where the real work of raising productivity and innovative capacity occurs, and where competition actually takes place."

Whereas the nation's scientific advancements are performed by the U.S. science workforce, employed primarily as faculty members and graduate students at the nation's research universities, the nation's advancements in engineering practice for purposeful technology development and innovation are primarily performed by the U.S. engineering workforce, employed as creative professionals in technology-based industry across the country.

As such, the U.S. engineering workforce in industry is the primary driver of U.S. technological innovation for competitiveness. Without continuous technological advancements, through the creative practice of engineering in industry, no amount of achievement in fundamental scientific progress can assure our economic prosperity and national security in the modern world. But the U.S. engineering workforce must be developed beyond entry level if we want engineering innovation to flourish in U.S. industry.

Finding 3: The Modern Practice of Engineering for Technology Development and Innovation has Itself Changed

During recent decades the modern practice of engineering for creative technology development and innovation has changed substantially from that portrayed by 1945 science policy. New realities have occurred in the technology development and innovation process that require new perspectives on U.S. engineering workforce development and on professional education for advanced engineering practice in industry.

Whereas the 1945 report, *Science; The Endless Frontier,*[4] emphasized that basic research was the forerunner of engineering for the generation of new technology and became U.S. science policy, the 1945 linear research-driven model of technology innovation is now recognized as erroneous and must be modified. The stakes in retaining U.S. technological leadership for competitiveness and defense are too high for this error to continue without reform in U.S. engineering education and practice.

As the Council on Competitiveness report *Picking Up the Pace* pointed out, the perspective that technology innovation is a linear process like a “relay race” where basic scientific research passes the baton to engineering for later development is outmoded.[5] The practice of engineering for technology development and innovation *does not occur* this way. A new paradigm of the practice of engineering for the creation (invention), design, development, and innovation of new, improved, and breakthrough technology has emerged for economic prosperity and the nation’s defense.

In today’s innovation-driven economy, the vast majority of engineering innovations are needs-driven and market-focused requiring deliberate engineering problem-solving, vision, and responsible leadership. Today the practice of engineering for creative technology development and innovation is a very purposeful and systematic practice, and is not a linear or sequential process following basic research as portrayed in 1945 (See Appendix A). Rather, engineering projects frequently drive directed strategic research efforts when necessary or anticipated to better understand the phenomena involved.

New technology is brought about primarily by a very purposeful and systematic practice of engineering involving the deliberate recognition of meaningful human needs and the deliberate engineering creation of new “ideas and concepts” to effectively bring about solutions to these real-world needs though responsible engineering leadership.

As a consequence, engineering practice and its resulting outcome, technology, have been redefined for the 21st century.[6] No longer should engineering be misconstrued as applied science. The practice of engineering involves vision, creative problem-solving, and responsible leadership to meet real-world needs. As William A. Wulf, president of the National Academy of Engineering, points out ─ “Engineering is design under constraint.” [7] As the *Phase* II Report, *Engineering 2020*, notes:[8]

- Engineering is a profoundly creative process
- Technology is the outcome of engineering
- Engineering is problem recognition, formulation, and solution

Finding 4: The Modern Practice of Engineering for Purposeful Technology Development and Innovation Mandates Reform of Professional Graduate Engineering Education for U.S. Engineering Workforce Development in Industry

Although the modern practice of engineering for systematic, technology development and innovation has changed substantially since 1945, the U.S. system of engineering graduate education has not kept pace with the modern paradigm. As the Committee on Science, Engineering, and Public Policy (COSEPUP) has pointed out, graduate education in engineering has evolved primarily in the United States as a byproduct of a national science policy for scientific research.[9] The United States has not had an effective system of professional graduate education during the last several decades for the vast majority of its domestic engineering graduates, whose professional careers are not centered on basic research but rather are centered on advanced engineering practice for creating, developing, and innovating new, improved, and breakthrough technology in industry for competitiveness and the nation's defense. As COSEPUP points out, "If scientists and engineers are to contribute effectively to national scientific, and technological objectives, their educational experience must prepare them to do so."

Whereas the nation has invested during the 1960's, 70's, 80's, and 90's in graduate education for the U.S. scientific workforce for basic research, we have not as a nation placed a balanced emphasis on investing in the further professional education of the nation's graduate engineers who enter industry and are the nation's primary creators, developers, and leaders of U.S. technological progress for competitiveness and national security. As a consequence of this unbalanced emphasis, lasting over four decades, the U.S. engineering workforce in industry is the nation's most underdeveloped resource for innovation. The nation is paying the price for long-term underdevelopment of the U.S. engineering workforce in industry that is showing up by a long-term decline in U.S. technological leadership and by a loss in our innovative capacity to compete. We now know 50 years later that one size or type of graduate education doesn't fit all.

Science and Engineering (S&E) are two different pursuits. They have two different missions, purposes, and objectives and for the most part are not sequential. As such, Science and Engineering (S&E) require two different types of education at the graduate level of practice. Thus, the modern practice of engineering for purposeful technology development and innovation mandates reform for a new type of professionally oriented engineering education at the graduate level to better develop the innovative capacity of the U.S. engineering workforce in industry for economic competitiveness and national security purposes.

The implications of this finding are far reaching. They have direct relevance in how engineers in industry practice engineering for purposeful technology development and innovation for economic competitiveness and for defense purposes and in how universities educate U.S. engineers for innovation. In essence, we cannot retain U.S. preeminence in engineering if the system of U.S. engineering graduate education does not reflect the modern practice of engineering for creative technology development and innovation or if we do not educate U.S. engineers for the highest levels of leadership responsibility required in the practice of engineering for effective technology development and innovation in industry.

Finding 5: Investment in the Development of the U.S. Engineering Workforce in Industry Can Accelerate U.S. Technological Leadership for Competitiveness and National Security

Whereas the United States has invested in building a formidable capability for basic research within the U.S. scientific workforce at the research universities, through research-base graduate education and must continue to do so, it has done so with an almost singular emphasis. Today, the nation must also invest in building a formidable capability for innovative engineering within the U.S. engineering workforce in industry through advancement of professional education oriented towards creative practice. As the Council on Competitiveness points out: [10]

- "Innovation is the engine of the 21st century economy. Successful companies will be those that continually invest in innovation ─ creating, developing and deploying new technologies, products, service and processes. Today, firms are increasingly relying on *intellectual and intangible assets* to sustain their competitive advantage and the market value of their firms."

- "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."

Although the universities have played a vital role in providing basic undergraduate engineering education to prepare young graduates for entry into engineering practice, there remains an innovation skills gap beyond entry level for responsible leadership of the technology development and innovation process. Lack of coherent professional education is limiting the growth of U.S. engineers for innovation. The education of an engineer must no longer be considered a one time event constrained to four years or that all of the knowledge and skills required of engineers for advanced practice can be developed in four years without experience.

Universities must engage in another important role, that is within their mission of professional education, by creating a new type of advanced professional education that nurtures the growth of their graduates beyond entry-level. Professional engineering education must become a process of lifelong learning and development that enables growth of engineer's as innovators and leaders throughout their professional careers. This requires professional engineering education to be specifically designed as an integrative process that combines experience, advanced studies and self-directed learning with creative engineering practice. More than ever before, the U.S. system of engineering graduate education must take a leadership role that promotes educational change if we want to tap the full innovative potential of the U.S. engineering workforce in industry.

Implementing this new university mission rises to a national priority because our domestic engineers are the fundamental building block of U.S. technology-based industry. America's competitiveness depends in large measure upon the innovative capacity of industry's core engineers to create, innovate, and lead on a continuous basis. This capacity in turn depends on the system of U.S. engineering graduate education to nurture the further growth of industry's core engineers on a continuous basis throughout their professional careers.

4. Recommendations ─ Setting the Agenda for the Next Steps for Action

Developing the innovative capacity of the U.S. engineering workforce in industry, through the deliberate advancement of professionally oriented graduate education, is a critical first step in accelerating U.S. technological leadership for economic competitiveness and for national security purposes.

4.1 Plan of Action

The National Collaborative Task Force on Engineering Graduate Education Reform proposes to initiate and guide a major reform in professional graduate engineering education by establishing new, innovative graduate programs for the advancement of creative practice and leadership of technology development in industry. The National Collaborative Task Force recommends the following plan for action.

Goal 1: To create an innovative model of advanced professional engineering education that is integrative with the practice of engineering, fosters lifelong learning, and enables growth of engineers beyond entry level in industry for increasing responsibility of technology development and innovation to ensure U.S. technological leadership for competitiveness

(a) Lifelong learning and growth in engineering practice for innovation & leadership
Create an innovative model of professional graduate education that fosters lifelong learning and enables growth of engineers as innovators and leaders throughout their professional careers in engineering practice from entry-level through chief engineer level of technological responsibility

(b) Aims of advanced professional engineering education
Whereas the intent of undergraduate engineering education is to prepare the engineering student with a basic foundation for entry into engineering practice, the intent of advanced professional engineering education is to enable the further growth and development of the engineer practitioner to his or her fullest creative, innovative, and leadership potential at the highest responsibility levels of engineering practice.

(c) Systems approach for curricular, educational process, and faculty development
Use a systems approach for curricular development, educational process development, and for faculty development in designing, developing, and implementing professional engineering graduate education that enables the growth of engineering practitioners throughout their productive careers for creative leadership for technology development and innovation in industry.

(d) Levels of growth and responsibilities in engineering practice beyond entry level
Define the nine progressive levels of growth, responsibilities, qualifications, and experience factor required in engineering practice beyond entry level for responsible professional leadership of technology development and innovation in industry from Entry-Level I /II Engineer through Chief Engineer Level IX (NSPE)

(e) Stages of career development beyond entry level in engineering practice
Classify the stages of career development in engineering practice in industry for responsible leadership of technology development and innovation

- Early career development — Level I Engineer through Level IV Engineer
- Mid career development — Level IV Engineer through Level VI Engineer
- Senior career development — Level VI Engineer through Level IX Engineer

(f) Framework of integrative profession education concurrent with engineering practice
Define a framework of integrative professional graduate engineering education that combines advanced studies, experiential learning, self-directed learning, and innovation-based learning in a manner concurrent with on-going engineering practice in industry

- Early career development — Define framework for Level I — IV Engineer Leading to the professional Master of Engineering Level IV Engineer — Project Level Responsibility
- Mid career development — Define framework for Level IV — VI Engineer Leading to the professional Doctor of Engineering Level VI Engineer — Program Level Responsibility
- Senior career development — Define framework for Level VI — IX Engineer Leading to — Policy Level Responsibility

(g) Innovation skills, experience, and knowledge required from Level I — IX Engineer
Define critical innovation skills, experience factor, and knowledge required for responsible engineering leadership of continuous technology development and innovation in industry

- Early career development — Define innovation skills, experience, and knowledge required for engineering leadership of technology development and innovation from Level I — IV Engineer — Project Level Responsibility
- Mid career development — Define innovation skills, experience, and knowledge required for engineering leadership of technology development and innovation from Level IV — VI Engineer — Program Level Responsibility
- Senior career development — Define innovation skills, experience, and knowledge required for engineering leadership of technology development and innovation from Level VI — IX Engineer — Policy Level Responsibility

(h) Curriculum that supports innovation & leadership skills from Level I – IX Engineer
Align a coherent professional curriculum that supports innovation and leadership skills at every level of engineering responsibility in industry from Level I Engineer ─ IX Engineer

- Early career development ─ Align a coherent professional curriculum that supports critical innovation skills, experience, and knowledge required for engineering leadership of technology development and innovation from Level I ─ IV Engineer ─ Project Level Responsibility

- Mid career development ─ Align a coherent professional curriculum that supports critical innovation skills, experience, and knowledge required for engineering leadership of technology development and innovation from Level IV ─ VI Engineer ─ Program Level Responsibility

- Senior career development ─ Align a coherent professional curriculum that supports critical innovation skills, experience, and knowledge required for engineering leadership of technology development and innovation from Level VI ─ IX Engineer ─ Policy Level Responsibility

(i) Educational process that enables growth and engagement in creative practice
Define an integrative educational process which provides enriching learning experiences and enables growth of practitioners in a manner concurrent with engineering practice.

1) Advanced studies
2) Self-directed learning
3) Experiential learning
4) Innovation-based learning
5) Technology development project/industry's need

(j) Attributes of high-quality professional education already demonstrated across U.S.
Build upon attributes of professional education that nurture positive development and enable growth of working professionals employed in engineering practice in industry

1) Cultures that support collaborative learning, creativity, and innovation
2) Planned studies with tangible outcomes
3) Learner centered education rather than teacher-centered instruction
4) Manner by which experienced engineers learn in creating / developing technology from Novice → Competent Engineer → Expert → Engineer-Leader
5) Learning environment of core faculty of practitioner-scholars from the university, adjunct faculty of distinguished leaders from industry, a student body of experienced practitioners from regional industry

Goal 2: To establish Graduate Centers for Advanced Studies in Technology Development, Innovation and Policy as a National Demonstration Project for pilot implementation across the U.S. to accelerate regional innovation for economic development and competitiveness

(a) Strategy for innovative start-up

The National Collaborative Task Force proposes a national demonstration project to implement this reform by establishing Graduate Centers for Advanced Studies in Technology Development, Innovation and Policy. The pilot demonstration project would begin with five to ten graduate centers in different states across the country.

- Using a systems approach under the guidance of a National Project Office, the Graduate Centers will work together and in partnership with regional industry.
- Start-up funding will be leveraged between government, industry, and foundations who are stakeholders in developing a strong U.S. engineering workforce to enhance local, statewide, and regional innovation for competitiveness.
- The National Demonstration Project will build upon attributes of professional graduate education already proven across the country (Council of Graduate Schools). [11]

(b) Justification of Graduate Centers

Justification for establishing the Graduate Centers across the country is straight forward: Providing a cost-effective opportunity for enhancing the innovative capacity of the U.S. engineering workforce in industry is critical in accelerating U.S. competitiveness.

- The innovative strength of the U.S. engineering workforce, the strength of the U.S. system of engineering graduate education, and the creation of economic prosperity of the United States are intertwined.
- Engineering fuels technological innovation … Technological innovation fuels the nation's strength for competitiveness, economic growth, creating jobs, and sustaining our national security …The innovative capacity of the U.S. engineering workforce must be nurtured to unleash the potential of U.S. creativity on a continuous basis.

(c) Clusters of professional graduate education for engineering innovation and leadership

The Graduate Centers will serve as statewide clusters of advanced professional education for innovation. They will be designed specifically to further develop the innovative capacity of practicing engineers working in regional industry.

- Graduate Centers will focus on professional engineering education for innovation and leadership; engage industry in the professional education process; and foster closer partnerships between universities and regional industry across the country ─ all working together to enhance U.S. innovative capacity and competitiveness.
- As industry's engineers grow and develop, so grows industry's innovative capacity and competitive advantage for economic development, locally, statewide, and globally.

(d) Sustainability beyond initial start-up
The Graduate Centers will be designed for long-term sustainability and cost-effectiveness beyond initial start-up.

- Long-term financing will pattern that of other professional schools, such as law, including working endowment from friends of the Centers, industry, and tuition.

- The focus will be on student-centered learning and on professional scholarship rather than on research with lasting outcomes to industry far exceeding the tuition cost.

- The Graduate Centers will draw their teaching strengths from the formidable engineering talent within regional American industry and from core professionally oriented faculty within regional universities, thereby creating an experienced faculty of professionals second to none.

- The Graduate Centers will implement an innovative faculty reward system reform to sustain excellence in professional scholarship, teaching, and engagement of professionally oriented core faculty and visiting faculty from industry

Goal 3: To replicate the Graduate Centers in all 50 states to accelerate U.S. engineering workforce development across the country that enables U.S. preeminence in technological innovation to enhance competitiveness using the combined strengths of industry and regional universities that will be second to none

(a) Strategy for growth across the United States
Grow 5 Graduate Centers per year over 10 years until all 50 states have capability for advanced professional education in engineering for innovation for economic development

(b) Strategy for continuous educational innovation, and improvement
Develop an organizational culture for continuous assessment and continuous innovation that sustains excellence of the Graduate Centers for long-term growth of the U.S. engineering workforce in industry to accelerate U.S. technological leadership

- Develop Graduate Centers around a core faculty of professionally oriented teachers and scholars within regional universities, and around an experience, distinguished adjunct faculty from regional industry in each state across the country

- Recruit a world-class student body of experienced practitioners at all levels of engineering leadership in each state who together with the combined teaching faculty will represent the growing innovative capacity of the United States in all regions of the country at the cutting edge of technology second to none for competitiveness

- Recruit world-class advisory boards for each Graduate Center that are comprised of distinguished professionals from industry and from universities who share a mutual vision for advanced professional education for advanced technology development and innovation

4.2 Impact ─
Economic Multiplier for Economic Growth and Competitiveness

The collective impact of creating new Graduate Center as a National Demonstration Project to improve local, state, and regional innovation across the United States is significant.

(a) Economic Multiplier per Graduate Center

- Develops core engineers as innovators and leaders in regional industry and concurrently develops new technology projects for economic competitiveness simultaneously
- Develops 100 engineers within regional industry annually who innovate 100 technology development projects for enhanced economic development within state-wide industry
- Unleashes America's creative potential in engineering for local and statewide economic development
- Estimated creative value of $ 500,000 per technology project, amounts to 5 million dollars of new technological innovation for economic development per state annually
- Impacts the technological development, innovation capacity, and competitiveness of at least 5 to 10 technology-based companies per state annually

(b) Economic Multiplier for the National Demonstration Project ─ For 10 Graduate Centers

- Develops core engineers as innovators and leaders in regional industry and concurrently develops new technology projects for economic competitiveness simultaneously
- Develops 1000 engineers within regional industry in 10 states annually who innovate 1000 technology development projects for economic development across 10 states
- Unleashes America's creative potential in engineering for local and statewide economic development in 10 states
- Estimated creative value of $ 500, 000 per technology project, amounts to over 50 million dollars of new technological innovation for economic development for 10 states annually
- Impacts the technological development, innovation capacity, and competitiveness of at least 25 to 100 technology-based companies within 10 states annually

(c) Economic Multiplier across the United States ─ For all 50 States

- Develops core engineers as innovators and leaders in regional industry and concurrently develops new technology projects for economic competitiveness simultaneously
- Develops 5000 engineers within nationwide industry in 50 states annually who innovate 5000 technology development projects for economic development across all 50 states
- Unleashes America's creative potential in engineering for local, statewide, and national economic development in all 50 states
- Estimated creative value of $ 500, 000 per technology project, amounts to over 2.5 billion dollars of new technological innovation for economic development for 50 states annually
- Impacts the technological development, innovation capacity, and competitiveness of at least 50 to 250 technology-based companies across the United States unleashing the innovative capacity of the U.S. engineering workforce for global competitiveness second to none

5. Path Forward: Next Steps for Action in the National Interest

The work of the National Collaborative Task Force is a work in progress. The transformation is underway but we still have a long way to go. Whereas the United States must continue its commitment to basic research and to the development of the U.S. scientific workforce, the United States must increase its commitment to the advancement of professional education for development of the U.S. engineering workforce in industry. Investing in the development of the U.S. engineering workforce for innovation in industry is critical in retaining U.S. technological leadership. While reform of K-12 education is necessary to attract the nation's creative talent into engineering, it is insufficient. The need for reform must extend into graduate education to unleash the innovative potential of the nation's engineers throughout their productive years of creative engineering practice in industry. The education of an engineer is truly a process of lifelong learning, growth and professional development that continues beyond the rudimentary level of entry level preparation.

If the United States is to retain preeminence in creating new technologies, new models for professionally oriented graduate education must be implemented that better support the professional development needs of the U.S. engineering workforce in industry. Universities have a vital role to play in economic development by providing professional education for their graduates who are the creators, entrepreneurs, and leaders of industry's technological thrust. The recommendations put forth by the National Collaborative are based on two guiding tenets. First, engineering education does not end at entry level if we want to unleash America's engineering potential for competitiveness. America's technological thrust requires an experienced, well-educated U.S. engineering workforce that is further nurtured at all levels of engineering practice to fuel preeminence for world-class technology development and innovation. Second, closer collaboration between industry and universities will be critical to the success of this reform. The next steps of the Task Force are to implement these recommendations into action in the national interest. This initiative has major educational and economic impact in stimulating continuous technology development and innovation in industry, retaining and creating jobs in America's industry, and sustaining U.S. technological leadership for economic competitiveness.

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Appendix A

Engineering Process for Needs-Driven, (Market-Focused) Technology Development & Innovation in Industry

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Needs → Engineering → Technology

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Directed Scientific Research to gain a better understanding of phenomena when needed or anticipated during the technology development project

Appendix B

Stages of Professional Maturation, Autonomy, and Responsibilities in Engineering Practice for Responsible Technology Leadership

<u>**Stages of Growth**</u>	<u>**Typical Responsibilities-Autonomy-Judgment**</u>
ENGINEER IX	An engineer-leader at this level is in responsible charge of programs so extensive and complex as to require staff and resources of sizeable magnitude to meet the overall engineering objectives of the organization.
ENGINEER VIII	An engineer-leader at this level demonstrates a high degree of creativity, foresight, and mature judgment in planning, organizing, and guiding extensive engineering programs and activities of outstanding novelty and importance. Is responsible for deciding the kind and extent of engineering and related programs needed for accomplishing the objectives of the organization.
ENGINEER VII	In a leadership capacity, is responsible for an important segment of the engineering program of an organization with extensive and diversified engineering requirements. The overall engineering program contains critical problems, the solutions of which require major technological advances and opens the way for extensive related development.
ENGINEER VI	In a leadership capacity, plans, develops, coordinates, and directs a number of large and important projects or a project of major scope and importance. Or, as a senior engineer, conceives, plans, and conducts development in problem areas of considerable scope and complexity. The problems are difficult to define and unprecedented. This involves exploration of subject area, definition of scope, and selection of important problems for development.
ENGINEER V	In a leadership capacity, plans, develops, coordinates, and directs a large and important project or a number of small projects with many complex features. Or, as an individual principle engineer, carries out complex or novel assignments requiring the development of new or improved techniques and procedures. Work is expected to result in the development of new or refined equipment, materials, processes, or products. Technical judgment knowledge, and expertise for this level usually result from progressive experience.
ENGINEER IV	Plans, schedules, conducts, or coordinates detailed phases of engineering work in part of a major project or in a total project of moderate scope. Fully competent engineer in all conventional aspects of the subject matter of the functional areas of assignments. Devises new approaches to problems encountered. Independently performs most assignments requiring technical judgment.
ENGINEER III	Performs work that involves conventional types of plans, investigations, or equipment with relatively few complex features for which there are precedents. Requires knowledge of principle and techniques commonly employed in the specific narrow areas of assignments.
ENGINEER I/II (Entry Level Engineer)	Requires knowledge and application of known laws and data. Using prescribed methods, applies standard practices/techniques under direction of an experienced Engineer.

Appendix C

Demographics of the U.S. Engineering Workforce: The Untapped Resource for Technological Innovation

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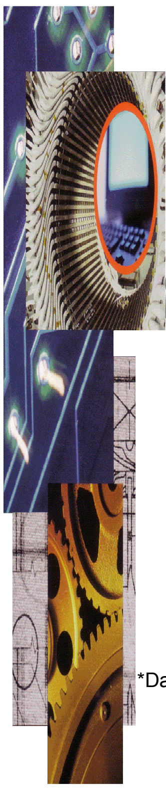
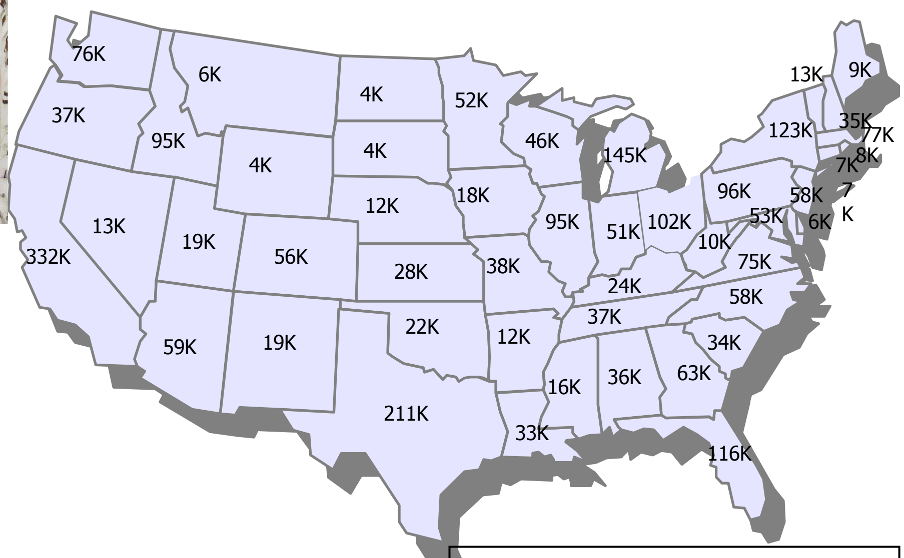


Professional Education for Engineers –

Demographics of the U.S. Engineering Workforce:
The Untapped Resource for Technological Innovation



*Data from the United States Bureau of Labor Statistics
http://www.bls.gov/oes/2001/oes_nat.htm
http://www.bls.gov/oes/2001/oessrcst.htm

Total for U.S and Territories:
2,489,070

National Collaborative Task Force – Developing the U.S. Engineering Workforce in Industry

Appendix D

Guidelines for Engineering Education Reform to Develop Professionally Oriented Graduate Education to Enhance the Innovative Capacity of the U.S. Engineering Workforce in industry

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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 Chief Engineer 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 & innovation