THE ADVANCED PROFESSIONAL EDUCATION OF GRADUATE ENGINEERS IN INDUSTRY FOR TECHNOLOGY LEADERSHIP

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1. INTRODUCTION

Following a review of graduate engineering education and needs assessment studies of graduate engineers in industry, it is now evident that a transformation in graduate education is needed to improve U.S. technology innovation and competitiveness in the worldwide economy. At present, graduate education in engineering is primarily a byproduct of research, based on a science-driven model of technology largely set in place in 1945 by the Bush report, "Science: The Endless Frontier."[1] It is now apparent, after 50 years, that this model is only partially correct. Based on a new understanding of the technology innovation process, it is now evident that technology innovation is primarily a deliberate and systematic needs-driven process using the creative engineering method. Correspondingly, a graduate professional education alternative which furthers the growth, learning, and creative development of the nation's in-place graduate engineers in industry can significantly improve U.S. technological competitiveness.

2. THE RESEARCH DRIVEN MODEL FOR GRADUATE EDUCATION

While the research-driven model of graduate education has served the nation well in the education of future academic researchers, it is now recognized that an alternative model of graduate professional education is required for the majority of the nation's graduate engineers in industry and government service who are pursuing non-research professional career paths. Based on this new understanding, it has become evident that the nation's primary "wellspring" for the generation, creation, and innovation of technology is its human resource base of creative graduate engineers in industry. Graduate professional education programs that are specifically designed to further the leadership growth and creative development of this vital national asset will directly and immediately stimulate effective innovation for improvement in worldwide competitiveness.

2.1 The Traditional Model of Education and Research

Education means different things to different people. The lack of an appropriate definition of education for human resource development has limited the advancement of professional education at research universities and the fullest interactions of these institutions with industry. Specifically, reference is made to the further graduate professional education of experienced in-place graduate engineers who are vital to improving industry's innovation and technological competitiveness.

Traditionally, the model of professional education for graduate engineers derives from a concept of knowledge transfer and learning which is the result of the science-driven model of technology. The existing policy for graduate science education was put forth in the Bush report to the president which outlined a program for continual technological progress after World War II.[1] This report was a landmark, and it set the stage for national investment in postwar scientific research and graduate research-oriented education which led to America's rise in graduate scientific research.

The Bush report built heavily on four main themes. First, that technology is science-driven and flows from basic research which is the foundation upon which all technical progress is ultimately built. As the report stated, "Progress depends upon a flow of new scientific knowledge. New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature and the application of that knowledge to practical purposes. Similarly, our defense against aggression demands new knowledge so that we can develop new improved weapons. This essential new knowledge can be obtained only through basic scientific research… Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn… Basic research is the pacemaker of technological progress." Second, that "… the responsibility for the creation of new scientific knowledge — and for most of its application — rests on the small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research … the number of trained scientists available … So in the last analysis, the future of science will be determined by our basic educational policy." Third, that to ensure technological progress, the federal government was obligated to ensure basic scientific progress and should invest in the graduate research-oriented education of its future scientists. Fourth, that the most effective way to advance science and technology was to award research funds to the most capable universities in the nation, which were therefore the "generators" of the nation's future technology and its future scientists.[1]

2.2 Graduate Education Policy for Scientific Research

Graduate research education, funding, research faculty, and curricula to enrich the graduate scientific research path was largely built into the nation's engineering schools in the 1960's, 70's, and 80's. Consequently, American engineering education has primarily patterned the science-driven model of graduate education which is in-place at the graduate level at the nation's research universities. The universities have performed an outstanding job in meeting the science education and research goal. Those graduate engineers who are pursuing scientific research career paths have been especially well served. The nation is preeminent in graduate education for scientific research. This model of graduate education is patterned worldwide.

The effects of the Bush report have been pervasive throughout higher education worldwide, specifically in the ranking and funding of research universities and in programs of graduate research-oriented education, wherein technology is defined by conventional educational thinking as "applied science" based on Bush's linear model of scientific research-driven technology. In the same context, the National Science Foundation (which Bush founded) has defined for several years the term "development" as technical activities of a non-routine nature concerned with translating research findings or other scientific knowledge into products or processes. In essence, the conventional university scientific research and education model for the profession(s) has evolved as:

curiosity • basic research → knowledge → teaching → learning → application in practice.

3. GRADUATE PROFESSIONAL EDUCATION

The Bush report, with all of its evidence and rightful justification for national investment in basic scientific research, was only partially correct. It misled the president and the nation because it virtually ignored the multitude of effective technologies generated by the nation's graduate engineers in industry and government service, which were brought forth through the needs-driven creative engineering method for responsible leadership of innovation and technology development. Yet, after three decades, higher education at engineering schools is still primarily tied to the singular linear research model of science-driven technology development. There, the goals are viewed primarily as teaching undergraduates and, at the graduate level, as research for the discovery and dissemination of new scientific knowledge and the graduate education of future teachers and academic researchers. At present, the graduate education of engineers has evolved as a byproduct of educational policy for scientific research.

3.1 Needs-Driven Model of Innovation and Technology Development

Although the Bush plan has proven to be correct for excellence in scientific research and graduate science education at universities to promote scientific progress, it is fundamentally in error for innovation and development of the nation's future technology and for the professional education of its graduate engineers in industry to promote technology progress to meet real-world societal needs. The findings presented in the U.S. Department of Defense study, "Project Hindsight," indicate that innovative technology development is primarily a deliberate and systematic needs-driven creative practice of engineering.[2] The purpose of the investigation was to determine the contributions of the science-driven approach and of the needs-driven engineering approach to America's acquisition of military systems technology capability. The findings of the study are that the key contributions to military systems technology since 1945 are: basic scientific research contributed .3% , applied research 7.7% , and needs-driven creative engineering development contributed 92%. Of this work, 49% came from industry, 39% came from U.S. Department of Defense government laboratories, 9% came from the universities, and 3% came from other agencies.

The lessons learned from Project Hindsight apply directly to civilian technology development as well. They indicate a need to establish an engineering education policy to enhance technology competitiveness for economic growth in the 21st century. The lessons learned are threefold. First, that technology progress in wartime or peacetime is accelerated by real needs and the flow of new ideas which help to create solutions to these needs. Second, that there are two primary approaches to the acquisition of new or improved technological capability; the science-driven approach and the needs-driven creative engineering approach.
Of the two primary approaches, the "lion's" share of technology is generated by deliberate and systematic needs-driven creative engineering development from exploratory development for proof of feasibility and concept through advanced engineering systems development for operational quality and capability, for cost-effectiveness, safety, environmental protection and customer use. Third, that the primary source of the nation's future technological capability for economic growth, for improvement in the quality of life, and for ensuring national security is the nation's human resource base of creative graduate engineers in industry and government service.

3.2 Needs-Driven Model of Technology Innovation and Graduate Professional Education

It is now recognized in the United States, and in other nations, that the pursuit of scientific research and the pursuit of needs-driven innovative technology development are two distinct activities and processes with distinct missions.[3] The purposes, methods, and talents of the people who engage in these endeavors are normally very different. As Martino points out, "… there is no neat linear progression from one into the other, as the traditional model implies."[4] Correspondingly, the models of graduate education for scientific research and of graduate professional education for creative engineering practice and leadership of innovative technological development are different. Each educational model must be supportive of the activity and intellectual creative process for which it is intended. As Walker, former chairman of the National Science Foundation Board, pointed out, "Teaching research isn't teaching engineering… the key idea is that engineering is a system of management that results in the satisfaction of human needs… and, the effectiveness of an engineer is measured by how well he or she invents and innovates to meet these needs."[5]

4. GRADUATE EDUCATION FOR INNOVATION AND LEADERSHIP OF TECHNOLOGY

At present, there is no coherent educational policy in the United States for the graduate professional education of in-place engineers in industry, beyond their formal first degree education. This is primarily because of the existing pervasive belief that technology is science-driven and is first generated at the universities by academic scientists and is then transformed into new technologies through engineering practice in industry as a linear transfer process. As pointed out in the 1995 National Academy of Sciences report, it is now apparent that the graduate education of engineers is largely a byproduct of national policies that support research.[6] In effect, there is no coherent policy for human resource development of graduate engineers in industry as there is for the education and training of the nation's academic scientists and researchers.

As the NAS report pointed out, "Although it is clear that human resources are the primary key to the nation's strength in science and technology, we, have not, as a nation, paid adequate attention to the graduate schools as a system for meeting the full range of needs for advanced talent in science and engineering … 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."[6] As the report pointed out, "In view of the broad range of ways in which scientists and engineers contribute to national needs, it is time to review how they are educated to do so."[6] In this context the report clearly noted that most graduate engineers are pursuing non-research careers.

Consequently, as the report pointed out, "If scientists and engineers are to contribute effectively to national, scientific, and technological objectives, their educational experience must prepare them to do so." As the report noted, "… there is room for substantial improvement in graduate education" … and … "graduate education must also serve better the needs of those whose careers will not center on research."[6]

4.1 The Role of Creative Engineer-Leaders in Industry

It is now recognized that the primary responsibility for the generation, creation, development, and leadership of needs-driven technology innovation is dependent upon that small group of men and women in industry and government service who understand the fundamental laws of nature and are skilled in the techniques of creative engineering development and responsible professional leadership — the nation's engineers who actually do creative development work and who lead the innovation process in industry. These in-place professionals are the pacesetters and the creative lifeblood and "wellspring" for technological innovation in America's industry.

Leadership of needs-driven technology innovation and industrial development is a unique multidimensional professional practice of increasing responsibility. As Deming pointed out, traditional management principles of direction and control are no longer sufficient in leading creative professionals in this process.[7] Neither are traditional didactic educational concepts of knowledge transmission and acquisition, as practiced at the universities, sufficient in educating imaginative professionals for meaningful innovative engineering work. Correspondingly, the myth that technology continually evolves primarily from science, or somehow occurs in the world for managers to recognize and then exploit for economic gain, is now seen to be fundamentally in error, and can lead to disastrous results for industry. Leadership of needs-driven technology innovation, creative invention, and the development of technology in industry is a deliberate and systematic process requiring wisdom and value judgement to find, identify, or anticipate meaningful hopes, wants, and needs of people for a better future. It includes the use of known "innovation best practice" methods, and the development of an organizational culture wherein industrial creativity and innovation can flourish to create effective solutions to meet these real human needs. It is now understood that there are five primary ingredients in successful industrial innovation. As Mueller has pointed out, these ingredients include: the need; the idea; the man or women (champion); the organizational culture; and adequate support, funding, and resources to permit the innovation to occur.[8]

4.2 The Professional Dimensions of Technology Leadership for Innovation

The further graduate educational development of engineers who can lead the innovation process is vital to improvement of effective innovation and technology competitiveness. Clearly, we shall have either slow or rapid technological progress depending on the nature of graduate education and on the number of highly qualified graduate professional engineers who are developing technology and leading the process of technological innovation in industry. A key factor in promoting the technological progress required for industry to remain competitive in the worldwide economy is provision of the opportunity for high-quality graduate professional education at the universities to further nurture and help these experienced in-place graduate engineers in industry to grow to their fullest creative and leadership potential.

It is now evident, therefore, that the national policy for education and the nation's propensity for innovative technological competitiveness are inextricably linked. Based on actual educational needs-assessment studies of in-place graduate engineers in industry and the known stages and dimensions of professional growth in the practice of engineering, it is now evident that there are nine stages of growth, proficiency, and responsible engineering leadership beyond undergraduate pre-professional entry level education. These levels of growth range from beginning project engineer through executive engineer leadership levels of professional responsibility, value judgement, program making, and technology policy making. As Wickenden pointed out, undergraduate entry level engineering education prepares the young graduate for beginning professional work at the first level… additional progressive engineering experience and graduate professional education is necessary for the in-place graduate engineer to grow to higher leadership levels of engineering attainment and professional responsibility.[9]

Accordingly, the model of graduate professional education for in-place graduate engineers in industry is neither a follow-on nor a byproduct of graduate education for scientific research nor is it simply an extension of content and method of pre-professional undergraduate education. In fact, it is different because the aims are different, as are the professional maturity factors, experiences, and objectives of graduate engineers. As Cranch has pointed out, everything can't be taught in the already saturated undergraduate engineering curriculum, nor have undergraduate engineering students reached the level of professional maturity to grasp certain professional issues.[10]

Because of the inexperience of undergraduates, and their stage of professional maturity, many of the professional dimensions cannot be developed until later years in graduate professional education and after the graduate has gained an established technical competency and an in-depth industrial experience base in practice.

The professional dimensions of the systematic engineering practice and professional leadership of needs-driven innovation and technology development are now known. They include:

- technical competence,
- creative problem-solving, systems thinking, and innovation,
- professional responsibility,
- professional leadership of multidisciplinary groups for needs-driven collaborative creativity,
- problem finding and visualization (needs-finding),
- program making and strategic thinking,
- policy making, value judgement, ethics in technology-social-safety-economic issues.

5. UNIVERSITY - INDUSTRY GRADUATE EDUCATION FOR INNOVATION

There is now both the conceptual clarity and factual basis for broad national support and implementation of high-quality post-graduate professional education of in-place graduate engineers in industry who are the nation's critical human resource for leadership of the needs-driven innovation and technology development. It has become evident that universities must serve two vital functions in higher education at the graduate level: (1) to be centers of excellence in scientific research to continually advance science and our understanding of natural phenomena; and, (2) to be centers of excellence in graduate professional education for innovation and leadership in the professions. Thus, universities must stand as cathedrals of learning and human resource development, serving not only to educate future scientific researchers, but also to educate future creative leaders in the professions. Now more than ever, universities must reassess their professional education mission and set a new direction more responsive to the growth needs of the professions whose mission is to meet real-world societal and industrial needs.

The mission of graduate education must be broadened in order to improve creativity, flexibility, and versatility within the practicing engineering profession in industry. It is timely, and of great national importance, that progressive universities enhance the graduate professional education of in-place graduate engineers — as innovators and leaders — who can nurture and develop the nation's future technological progress and competitiveness. This reform can be effected "… without disruption of the traditional commitment to excellence in basic research that has been, and must continue to be, a hallmark of the system of graduate education."

5.1 University-Industry Graduate Centers for Technology Innovation and Leadership

The prospect is clear. Improvement of U.S. innovation and technological competitiveness is strongly influenced by improvement of the acquisition stage of technological capability. Key to improvement of this creative technological process is a nurturing industrial culture of leadership for innovation, and a university culture of graduate professional education that provides the opportunity and stimulation that permits the nation's in-place graduate engineers in industry to grow professionally.

The transformation in America's engineering education infrastructure has begun at the undergraduate level with the increased emphasis placed upon engineering design projects and multidisciplinary teams. However, the major area for transformation is at the graduate professional level — to continue the graduate professional educational growth, and career-long development of the majority of the nation's engineers, beyond entry level, who are pursuing professional careers which are not centered on research, but aimed toward responsible professional leadership of needs-driven technology development in industry and government service. The fullest development of this vital human resource is necessary for the nation's continual technological progress and is crucial to the nation's prosperity.

The transformation at the nation's engineering schools will require planned change and educational innovation to complement predominantly research-oriented cultures, curricula, and faculty with new practice-oriented graduate centers for innovative engineering and graduate professional education for leadership of technology. Therefore, the authors recommend that regional centers be established throughout the nation between leading universities and regional participating industry for practice-oriented graduate professional education in engineering innovation, technology leadership, and policy. As models in the nation, the centers will serve as unique "teaching and technology development" centers for engineering innovation and high-quality graduate professional education for engineers in regional industry.

5.2 The Need for Advanced Professional Education for Engineers

The need for graduate professional education for in-place graduate engineers in industry is substantial and is national in scope. Most of the nation's graduate engineers enter industry or government service immediately after completion of their first formal degree education. A few remain at the universities, however, to pursue graduate work as graduate assistants in preparation for future teaching and academic research careers at universities. However, as Garry, former vice president of corporate engineering and manufacturing at General Electric Company, has pointed out, "… only 5 % of the engineers in the U.S. report their primary task as being research, and only about 1 % indicate that they do basic research."[11] Most of the nation's engineers are employed in industry. Of this group, "Development is the primary task of engineers … and … Great engineering is measured by the proper gauging of people's needs and the delivery of affordable, high-grade products and services."[11]

Cranch noted that most of these graduate engineers rise to positions of professional leadership responsibility within their organizations.[10] However, because of the lack of a coherent national policy for the advanced professional education of engineers this majority of graduate engineers is the nation's underdeveloped creative human resource in science and technology. The need to continue the developmental growth of these practitioners in the engineering profession is substantial. As Houle points out, "Too few professionals continue to learn throughout their lives, and the opportunities provided to aid and encourage them to do so are far less abundant than they should be."[12]

The need to enhance graduate professional education for the nation's in-place graduate engineers in industry grows in importance as innovative competitiveness in the worldwide economy increases. Graduate professional education of this vital human resource can provide a "continuous pipeline for creativity, innovation, leadership and direction" for the nation's future technological progress. This need is representative across the nation. Accordingly, it is now apparent that the primary key ingredient in successive industrial innovation and improvement of U.S. technology competitiveness is the recruitment, retention, and human resource development of creative graduate engineers who are the "champions" and sources of the innovative "ideas," and who understand and lead the technological innovation process.

As Morita, chairman of Sony Corporation points out, "The challenge for all countries, not just ours, is management of new technologies, new development, and new products. We will need a lot of new ideas. Technology management will be the key to success for companies anywhere in the world in the coming years. Knowing how to make the best use of your engineers will be the test of whether a company will succeed in the coming age."[13]

5.3 Method and Approach to Graduate Professional Education for Engineers

The mission of the practice-oriented graduate centers will be to foster the development of engineer-leaders in industry and government service for responsible professional leadership of the nation's future technology, and to foster the development of needs-driven technology innovation, and policy, responsive to meaningful industrial and societal needs. The centers will provide high-quality graduate professional education which is more relevant to the stages of developmental professional growth and to the dimensions of professional leadership in engineering and more conducive to the manner in which advanced practicing professionals learn, grow, and develop in professional engineering practice. The regional centers will build on a new concept of graduate professional education which combines advanced studies in technology leadership concurrently with the practitioner's on-going experiential growth in actual engineering practice and creative technology development work in industry.

5.4 Curriculum of Concurrent Advanced Studies
With On-Going Technology Development in Industry

As national models, the purpose of the centers is to provide graduate engineering practitioners, in industry and government service, the opportunity and encouragement to continue their growth, learning and creative development as they assume increasing professional leadership responsibility of meaningful needs-driven creative engineering work. Because it is now recognized that leadership of needs-driven creative technology development is a unique professional practice, it is now evident that the professional education of engineer-leaders is more than simply combining traditional business courses with traditional engineering courses. The program will build on three modes of human resource development in the professions: (1) self-directed learning and inquiry; (2) professional-oriented instruction; and (3) actual creative performance in the professional practice and leadership of needs-driven innovation and creative technology development.[12]

The centers will enable experienced in-place graduate engineers in regional industry the opportunity to continue their graduate professional education and growth while employed full-time in industrial practice, and while pursuing full-time technology development work. Recognizing the unique blend of technical, professional, ethical, creative, and leadership dimensions, the initiative will set a new direction in graduate professional education for creative professional practice in innovative engineering and responsible leadership of needs-driven technology development. The program of graduate professional education is not intended to serve as a "stepping stone" along the PhD research-oriented path of graduate education, but rather as a path of excellence in its own right toward the highest leadership levels of professional engineering practice.

The focus is to provide a graduate professional education alternative that supports the process of developmental growth for the majority of the nation's graduate engineers in industry and government service. The curriculum is specifically planned and designed for experienced in-place graduate engineers who are pursuing responsible professional leadership careers, not centered on research, but on the creative engineering development of products, processes, systems, and operations responsive to real-world industrial and societal needs. The program's emphasis is on "doing-centered" learning, growth, and continued development of creative engineering practitioners. Accordingly, the professional-oriented curriculum will be specifically designed as a coherent matrix of advanced graduate studies which matches and supports actual assessed educational needs of engineers in industry, the dimensions of professional engineering practice, and the nine stages of developmental growth and increasing responsibility for leadership of technology development, beyond entry level. The curriculum will combine relevant advanced studies concurrently with the practitioner's on-going creative professional practice and technology development work in industry. In this manner, the centers will directly enhance technology competitiveness and human resource development, linking creative human resource development and the generation of needs-driven technological innovation to improve U.S. industrial competitiveness.

5.5 The Technology Development Thesis Project: A Quality Tangible Experience

Whereas traditional research-oriented graduate education is organized around an intensive research thesis experience, practice-oriented graduate professional education is organized around an intensive innovative technology development thesis experience which is directly relevant to societal or sponsoring industry's needs. As Conrad, Haworth, and Millar have been pointed out, "… a primary attribute of high-quality graduate experience is that the participants produce a tangible product, thesis or project report, which is of some value to the field as well as to them personally."[14]

Correspondingly, a main component of the curriculum is a needs-driven creative technology development project-thesis. The needs-driven thesis project serves to integrate the curriculum of advanced professional studies with the practice of the in-place graduate engineer. During the course of advanced studies, each professional participant will identify a meaningful real-world need of importance to society or to a sponsoring industrial organization, and will work in cooperation and collaboration with principal faculty members who will help guide the thesis project work. This practice-oriented approach provides both industrial sponsors and advanced practitioners an excellent method by which to study an area of concern to the organization and to stimulate creativity and technological innovation relevant to real-world needs. The needs-driven thesis project provides a synergism between high-quality graduate professional education and needs-driven technological innovation. The spin-off effects of these technology development projects, conducted at graduate centers across the nation, will directly and immediately enhance the nation's competitiveness and human resource base in creative technology development in industry many-fold.

5.6 Graduate Professional Education for Lifelong Growth and Creative Practice

As with other forms of professional leadership education, the development of creative technical leaders and innovators in engineering is a long-term growth process. As pointed out over fifty years ago, "… the aim of engineering education, broadly speaking, is to prepare men (and women) for entrance into the engineering profession."[15] Today, however, the aim of graduate professional education must be to continue the growth of the in-place graduate practicing professional, after entrance into the profession, toward his or her fullest creative and leadership potential in professional practice. As a long-term growth process, the development of leaders of technology begins in the early formative years of pre-professional undergraduate engineering education. However, the educational growth of creative graduate engineers is not constrained to four, five or eight years, but it is a long-term process of continuous growth and development of technical, creative, and leadership potential extending throughout the engineer-leader's career in creative professional practice.

Wickenden noted that, " … virtually all engineering problems fall on some one of three fairly distinct levels: (1) the level of known laws and data; (2) the level of technical judgment; and (3) the level of policy making … The engineer graduate will do well to recognize that his (her) training in college fits him only for the first of these levels. Training for the higher levels is yet to come. Most of it will be up to him. Experience together with specialization usually will carry him to the second level, but the time required and the area of coverage will depend largely upon the individual's interest and initiative. Experience and specialization alone will never carry him to the third level of responsibility. To reach it he will have to be qualified for a broader kind of thinking with more variables involved and many of them of a highly intangible character."[9] Wickenden also observed that, "Engineering consists not only in solving problems, but equally in making programs of execution. College teaches the rudiments of problem-solving, but little about program-making … much more than technical specialization is involved in the higher levels of engineering attainment. … This job of program planning is one of intricate co-ordination … It is not taught at college … It is one of the major goals of an engineer's post-college education …"[9]

6. SETTING A NEW DIRECTION: THE PATH FORWARD

It is now understood that the professional education of engineers is not a one-time event that is completed in the early years of a graduate's education. Rather, this is a process of lifelong growth, increasing professional development, and responsibility, wherein additional engineering experience of increasing responsibility as well as graduate professional education is necessary for the graduate engineer to grow to higher leadership levels of engineering practice. Based on this recognition, the graduate professional curriculum for technology leadership builds upon undergraduate engineering education as the basic educational foundation of fundamentals which prepares graduates for the practice of engineering at a professional level. The program of graduate professional education is intended to continue the advanced professional education of graduate engineers who have a minimum of at least two years of experience in creative engineering practice, affording them the opportunity to attain the highest levels in the professional leadership of technology innovation.

Accordingly, a major thrust of the centers is to foster an educational transformation that supports the concept of graduate professional education as a process that nurtures and supports lifelong intellectual growth, creativity, ethical and leadership development in the fullest spirit of needs-driven technology innovation and responsibility of the profession of engineering. The overall aim is to provide an integrated practice-oriented program of professional education to develop versatility, creativity, technical competence, flexibility, and innovative capabilities which are needed for the in-place professional to grow in responsible leadership of meaningful needs-driven creative engineering work. The concept of graduate professional education builds on an open-ended curriculum that fosters the developmental growth of the in-place graduate engineer as an emerging innovator and leader of technology, through the professional Master and Doctoral level, and beyond. In order to meet these aims and to implement this transformation, the centers will build upon the existing strengths of the university in collaboration with the professional engineering strengths and technological strengths of regional industry. The centers will provide a very cost-effective and feasible way in which to build high-quality and innovative practice-oriented graduate professional education programs of excellence. These professional programs will complement existing graduate research-oriented programs; adding revenue, national prestige, recognition, and strength to the associated universities.

6.1 The Faculty

One of the critical ingredients of this educational innovation is recruitment, development, and support of a strong professional adjunct faculty of distinguished, experienced engineer-leaders in industry. Combined with a solid core of resident engineering faculty and other distinguished faculty from the total university, these engineer-leaders would complement the existing graduate research-oriented academic base. These faculty would form an interdisciplinary and experienced faculty base within the center organization. The centers' organizational culture would encourage collaborative faculty creativity in teaching and innovation across "departmental and university boundaries," between participating universities, and with sponsoring industries. Such an organizational approach has the potential to draw experienced engineers from the practicing profession to build one of the strongest professional-oriented faculty in the nation with industry's help and sponsorship.

6.2 The Graduate Practicing Professional Student Body

A key component of this educational innovation is a student body drawn from the regional practicing profession of in-place graduate engineers in industry and government service. These qualified participants would have the creative and leadership potential and intrinsic motivation to continue to grow and become leaders, developers, and innovators of industry's future technological progress and competitiveness. The program of graduate professional education is specifically designed to foster the professional growth of experienced graduate engineers in industry and government service, who have a minimum of two years of experience, as technology leaders. The program is not designed for graduate students either just out of college or wishing to remain in graduate school. Rather it is designed to continue the full growth, learning, and creative development of the in-place experienced practicing professional in industry to higher levels of competency, leadership and professional maturity. The program extends to the highest leadership levels of professional practice.

Because most industries recruit graduate engineers from among the nation's various universities, the centers will enable these high-caliber graduate engineers to continue their advanced professional educational growth while employed full-time in industry. Consequently, the experienced practicing graduate professional student body will be a strong experienced group of the nation's finest engineers who are continuing their growth in the profession for leadership roles in industry. The program of graduate professional education is purposefully designed to continue the growth of graduate engineers, at whatever level they enter the professional program, through the Master of Engineering, the Doctor of Engineering, and beyond to the highest levels of technology leadership and professional practice.

The concept is based on the realistic model that most of the nation's graduate engineers are recruited and enter industry immediately after their first formal university degree. Consequently, as Conrad, Haworth, and Millar have pointed out, it is now known that graduate education in the United States is in transformation.[14] There is a new clientele of nontraditional graduate professional students whose educational growth needs and professional experiences are quite different from those of young traditional resident graduate students who are pursuing careers in academic basic research and teaching. Based on the results of the national study of graduate education, it is now evident that at the master's level over 90% of the participants are in the professional fields outside the traditional liberal arts and sciences. And over 50% are in the professions at the doctoral level. It is also now evident, as the national graduate study pointed out, that "… about one-half of all master's students are thirty years of age or older, and two-thirds are enrolled part-time."[14]

7. CONCLUSION AND NEXT STEPS TOWARD A NEW PARTNERSHIP

It is now clear that there are two distinct types of education and cultures at the graduate level: (1) graduate scientific education for research; and (2) graduate professional education for responsible service and creative leadership to meet meaningful real-world societal needs. These have different missions, purposes, participants, faculty, curricula, and methods. Without diminishing the importance of science-driven technology development, it is now understood that needs-driven technology development is the primary driving force for the nation's current and future technological progress. The nation's primary human resource for the generation, development and leadership of needs-driven technology innovation is the nation's in-place graduate engineers in industry and government service. Currently, there is no coherent educational policy for the graduate education of the nation's engineers. Their graduate education is primarily a byproduct of a national educational policy which supports research because of the science-driven model of technology.

It is now recognized that graduate education must also serve better the needs of those professionals whose careers are not centered on research, but rather are centered on solving real-world human needs which is the mission of the creative profession of engineering. While general support for research-oriented graduate education programs has been underway in the United States for over three decades, it is now compelling and timely to build graduate professional education programs into the nation's graduate education and technological infrastructure. There is now both the conceptual clarity and the factual basis to establish an alternative of high-quality graduate professional education for the nation's in-place graduate engineers in industry who are critical to leadership of the nation's future technological progress and competitiveness. This transformation can be made at the nation's universities through a unique partnership between the universities, industry, and government with neither disruption nor loss of integrity of the research mission which is a "hallmark" of traditional graduate scientific education. A program of general support to continue the graduate professional education of in-place graduate engineers in industry, beyond their formal first degree education, as innovators and leaders can have significant and immediate direct returns and benefits to improvement of U.S. innovation and technology competitiveness.

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