# AC 2007-284: FACULTY REWARD SYSTEM REFORM FOR ADVANCEMENT OF PROFESSIONAL ENGINEERING EDUCATION FOR INNOVATION: LOOKING AT REPRESENTATIVE CRITERIA FOR MERIT PROMOTION IN ADVANCED ENGINEERING PRACTICE IN INDUSTRY


**Roger Olson, Rolls-Royce Corporation**

ROGER N. OLSON is Lead Stress Engineer, Rolls-Royce Corporation, and a director of ASEE-College Industry Partnership Division.

**Samuel Truesdale, Rolls-Royce Corporation**

SAMUEL L. TRUESDALE is manager of employee development, engineering business improvement organization, Rolls-Royce Corporation, and program chair, ASEE-College Industry Partnership Division.

**David Quick, Rolls-Royce Corporation**

DAVID H. QUICK is Manager, R&D Customer Requirements, R&T Strategy, Liberty Works (tm) Rolls-Royce North American Technologies, and past chair ASEE-Corporate Members Council.

**Dennis Depew, Purdue University**

DENNIS R. DEPEW is dean of the college of technology, Purdue University.

**Gary Bertoline, Purdue University**

GARY R. BERTOLINE is professor and assistant dean for graduate studies of the college of technology, Purdue University.

**Mark Schuver, Purdue University**

MARK T. SCHUVER is director of the Rolls-Royce-Purdue Master’s degree program, Purdue University.

**Duane Dunlap, Western Carolina University**

DUANE D. DUNLAP is professor, interim dean, Kimmel School, Western Carolina University, and program chair ASEE-Graduate Studies Division.

**Donald Keating, University of South Carolina**

DONALD A. KEATING is associate professor of mechanical engineering, University of South Carolina, and chair ASEE-Graduate Studies Division.

**Thomas Stanford, University of South Carolina**

THOMAS G. STANFORD is assistant professor of chemical engineering, University of South Carolina.

# Faculty Reward System Reform for Advancement of Professional Engineering Education for Innovation: Looking at Representative Criteria for Merit Promotion in Advanced Engineering Practice in Industry

## 1. Introduction

This is the second of three invited papers prepared for a special panel session of the National Collaborative Task Force on Engineering Graduate Education Reform that is focusing on the criteria for merit promotion of engineers in practice in industry to set the stage for designing a new faculty reward system for faculty participating in the graduate level instruction of practicing engineers. This is complementary to the traditional research-oriented faculty reward system for advancement of professional engineering education. Using professional attainment guidelines in engineering practice for industry, government service, NSPE, and ASCE this paper sets the foundation for rethinking new unit criteria for professionally-oriented faculty at the nation's colleges of engineering and technology.

This paper describes how almost all engineers in industry now move ahead solely by merit pay increases and merit promotions by progressively increasing their abilities. It describes how engineers progress within a grade level, or from one grade level to another when capability is demonstrated, and not by seniority, or by cost-of-living increases. As such, the paper provides information for making a knowledgeable recommendation for a new unit criteria for faculty who teach, perform professional scholarship, and engagement oriented toward the creative practice of engineering, that should pattern and correlate closely with professional achievement criteria as put forth by the practicing engineering profession as a complement to unit criteria for research-oriented faculty.

## 2. The Professional Advancement Path for Engineers

In modern, high technology industries, engineers are a necessary, and a valued resource. These engineers create (invent), design, develop, and innovate to produce new / improved / breakthrough technologies. Most of these engineers enter the industrial workplace with a Baccalaureate degree. They progress up the professional ladder to increased compensation, and higher pay grades as their capability is demonstrated by a progressive gain in their abilities, and not by seniority. The process of Lifelong Learning for these engineers in industry is very necessary since the engineering profession is not static, but continues to advance rapidly. This learning is composed of on-the-job learning, company provided training courses, single courses from universities (continuing education), and gaining advanced (postgraduate level) degrees. The day of across-the-board cost of living increases, and/or progressing up the ladder by seniority is in the past.

See Appendix A for detailed descriptions of engineering job rankings by level, and a relation to academic levels.

## 2.1 Why Innovative (and up-to-date) Engineers are Needed in Industry

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 very purposeful and systematic practice. It is not the linear or sequential process following basic research as portrayed in 1945, by Vannevar Bush [1]. Rather, creative engineering projects in industry frequently drive the need for directed strategic research efforts at universities when necessary, or when anticipated, to gain a better understanding of the natural phenomena involved.

Contrary to popular belief, engineers do not simply apply existing technology to contemporary problems, or sequentially transfer results from basic research into development. What engineers apply is the engineering method combined with their accumulated professional skills, their creativity, their knowledge gained through study and experience, their judgment, and their leadership in the solution of real-world problems. By their innovative designs, and their conceptualization of new ideas and concepts, to meet real-world needs of people, engineers actually obsolete existing technology through their improvements and deliberate breakthroughs.

New technology is brought about 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 meet these needs though responsible leadership. Engineering practice, and its resulting outcome of technology, have been redefined for the 21st century.[2] Engineering must no longer be misconstrued as "applied science."

Rather, as William A, Wulf, president of the National Academy of Engineering defines the term, "Engineering is design under constraint."[3] As *Educating the Engineer for 2020: Phase II* Report *points* out:[4]

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

As the Council on Competitiveness points out ─ "Innovation will be the single most important factor in determining America's success through the 21st century" … "For developed nations, no longer able to compete on cost, the capacity to innovate is the most critical element in sustaining competitiveness"… However … "The United States could lose its preeminence in technology unless a new national innovation agenda is developed." [6]

## 2.2 To Achieve Technology Development & Innovation by Engineers, They Must Grow in Their Field

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. [5]

The United States has not had a coherent policy during the last several decades for the graduate development of its domestic engineering graduates in the U.S. engineering workforce. These are engineers whose professional careers are not centered on academic scientific research, but rather are centered on creating, developing, and innovating new, improved, and breakthrough technology in industry for competitiveness and the nation's defense. (See Appendix G)

Whereas the nation invested heavily during the 1960's, 70's, 80's, and 90's in the graduate education of the U.S. scientific workforce for basic academic research, we have not as a nation placed a balanced emphasis 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 purposes.

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. But, 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; have different missions and purposes; 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. The modern practice of engineering for creative 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 for competitiveness and national security purposes.

The implications of this finding are far reaching, influencing not only the way we conduct creative technology development and innovation for economic competitiveness and defense purposes; but also the way we educate U.S. engineers for innovation. 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 our engineers in industry for the highest levels of leadership responsibility required in the practice of engineering for effective technology development and innovation.

**3. Next Generation Professional Education for Lifelong Learning ─ Combining Advanced Professional Studies with Engineering Practice**

The Task Force believes that further postgraduate development of the U.S. engineering workforce in industry is critical to the development of the nation's capacity for continuous technology development and innovation which is the primary engine for the nation's economic prosperity and security.

U.S. engineering graduate education which serves as the primary infrastructure for the post-graduate development of the U.S. engineering workforce in industry has undergone a serious 'disconnect' with creative engineering practice. With notable exceptions, the creative engineering method that should be the hallmark of engineering practice has increasingly been abandoned in U.S. engineering graduate education. The 'disconnect' has been widening, and worsening, over a period of several years causing a "gap" in professional education for the U.S.

engineering workforce in industry ─ contributing to a long-term decline of U.S. innovative capacity.

To further exasperate the problem, the generation of experienced engineers who have led much of the creation, development, and innovation of U.S. technology since Sputnik is now retiring. By the year 2010, estimates indicate that over 30% of America's experienced, domestic engineering leadership base for technology innovation will have retired, causing a "brain drain" and a further loss in U.S. innovative capacity in engineering.

Because of long-term neglect in provision of U.S. professional engineering graduate education for creative engineering practice, the vast majority of America's engineers are not being further educated professionally beyond entry-level undergraduate education to assume these engineering leadership positions for technology development & innovation in industry. As a consequence, the nation is now paying the price of long-term neglect in the further professional graduate education of the U.S. engineering workforce in industry, which has been a contributing factor to the long-term decline of our nation's innovative engineering capacity in industry and to subsequent decline in U.S. technological competitiveness.

### 3.1 Accelerating Innovation through U.S. Engineering Workforce Development

Today, the U.S. engineering workforce in industry is the backbone of the nation's thrust for continuous technological development and innovation. If we want our nation's engineers to continue to grow beyond early career development responsibilities to reach their creative and innovative potentials, to do "over-the-horizon" engineering, and to become creators, innovators and leaders of new technology innovations throughout their professional careers, then this requires universities to create a new type of professional education for lifelong learning as a logical progression of growth beyond the professional masters level.

### 3.2 Reshaping Professional Engineering Education for Creative Practice

To meet the challenge, the National Collaborative Task Force is engaged in a complex project that requires a total systems approach. The stakes to enhance the innovative capacity of the U.S. engineering workforce for competitiveness are high.

Broad sweeping changes are needed for a new type of professionally oriented engineering graduate education that is combined with engineering practice and is designed for practicing engineers in industry and government service to spur innovation at the professional master of engineering level, the professional doctoral level, and beyond to the highest levels of engineering practice. But these changes won't occur by themselves without vision, commitment, leadership, and resolve.

Today, professional engineering education for working professionals must correlate with the modern practice of engineering including growth from project levels, technical program levels, through policy levels. As such, professional education for the practice of engineering is quite different from traditional graduate education for scientific research. The design of professional graduate education for creative engineering practitioners, who are emerging as innovators and leaders of technology development in industry, requires a different professional curriculum and approach than that presently used for the graduate education of academic research scientists. It requires a different type of faculty, approach, and focus.

### 4. Aims of Professional Education ─ Developing the U.S. Engineering Workforce in Industry

The education of an engineer is truly a process of lifelong learning, growth and intellectual development that continues beyond the rudimentary level of entry level preparation. Although the aims of traditional research-based graduate education are primarily focused on preparing future academic faculty for teaching and scientific research positions at the nation's universities, the aims of professional education are quite different.

Whereas basic undergraduate engineering education is designed to prepare the engineering student for entry into engineering practice with the foundation for lifelong learning, the intent of advanced professional education, for this practicing engineer, is to further his or her development beyond entry level to his or her fullest creative, innovative, and leadership potential at the highest levels of professional responsibility of engineering practice.

### 4.1 Focus on Education for Innovation and Leadership ─ To Strengthen the U.S. Engineering Workforce for Competitiveness

A new type of professionally oriented engineering graduate education is required that develops the innovative capacity of the U.S. engineering workforce for competitiveness and that better supports the innovation skills required of engineers at all levels of leadership responsibility in industry. The Task Force is leading the development of a new model of professional education for graduate engineers in industry focusing on innovation and leadership and solving unknown problems. Educating engineers as creative professionals is a career long process of growth and further professional development including the development of intrinsic creative and innovative potential for leadership in engineering practice. This process extends beyond entry level undergraduate education to the highest levels of responsible engineering leadership within the practicing profession. Professional education at this level requires an integrative combination of self-directed learning, experiential learning, innovation-based learning, and advanced studies combined with real-world experience in creative engineering practice.

The National Collaborative Task Force believes that the development of the engineer in industry or government service as a creative professional, innovator, and leader can be classified by three stages of growth:

- Early Career Development ─ From Level I Engineer through Level IV Engineer
- Mid-Career Development ─ From Level IV Engineer through Level VI Engineer
- Senior Career Development ─ From Level VI Engineer through Level IX Engineer

## 5. Conclusions: A Work in Progress ─

### 5.1 Why a postgraduate education for Engineers in Industry is needed

The United States needs a workforce that is nurtured at all levels of engineering practice beyond entry level to fuel America's preeminence for world-class technology development and innovation. Professional engineering education does not end at entry level or with professional master's level education if we want to unleash America's engineering potential for competitiveness and national security purposes. Second, close collaboration between industry and universities will be critical to the success of this reform. The Task Force believes that the further graduate development of the U.S. engineering workforce in industry can neither be done by universities working alone nor by industry working alone. Third, reinventing professional engineering education for creative engineering practice requires industry's steady and consistent input aimed at what we want the nation's engineers to do and to become. The next steps of the Task Force are to implement these recommendations into action in the national interest. [7 &8]

### 5.2 Properly compensating the Graduate Engineering Faculty for providing this needed postgraduate education for Engineers in Industry

Because of the need to continue the education of the engineers in industry that provide the innovation that drives the U.S. Economy, the University faculty members that provide this postgraduate education must be properly compensated relative to the engineers that they instruct.

The pay scales of these faculty members must fit on the scale of engineering levels as shown in Appendix A. If this is done, then the faculty will be more willing to assume these additional duties, and the postgraduate programs promoted by the National Collaborative for Engineering Graduate Education Reform, can take place.

**[Please review appendices B-F for additional information.]**

**Bibliography**


1. Science The Endless Frontier. A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, July 1945 ...
2. National Academy of Engineering, *Technically Speaking,* 2002.
3. Wulf, W. A., *The Urgency of Engineering Education Reform*, Main Plenary Address, Proceedings American Society for Engineering Education Annual Conference, 2002.
4. National Academy of Engineering, *Educating the Engineer of 2020: Phase II Report*, 2005
5. Committee on Science, Engineering, and Public Policy (COSEPUP), Reshaping the Graduate Education of Scientists and Engineers, National Academy Press, 1995.
6. Council on Competitiveness, *Innovate America*, 2005.
7. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* National Academy Press, 2006.
8. *Strategic Plan: Enabling a Strong U.S. Engineering Workforce for Competitiveness,* National Collaborative Task Force on Engineering Graduate Education Reform, 2006.

# Appendix A

## The U.S. Department of Labor Engineering Job Rankings, Levels 1 to 9

### ▶ Engineer Level 1 (GS-5)

This entry level of professional work requires a bachelor's degree in engineering and no experience, or the equivalent of a degree in appropriate education and experience. Assignments are designed to develop professional work knowledge and abilities. (Terminal positions are not included.) Works under close supervision on required tasks. Work is checked during progress. No responsibility for direction of others.

### ▶ Engineer Level 2 (GS-7)

This professional level performs routine engineering work requiring application of standard techniques, procedures, and criteria in carrying out engineering tasks. Limited judgment on details of work and in making preliminary selections or adaptations of engineering alternatives. Requires work experience acquired in an entry-level position, or appropriate graduate-level study. Assignments may include work that is typical of a higher level. (Terminal positions are not included.) Supervisor screens assignments, and selects techniques and procedures. Receives close supervision. May be responsible for the direction of a few aides or technicians.

### ▶ Engineer Level 3 (GS-9 or Academic Instructor)

Independently evaluates, selects, and applies standard engineering techniques, procedures, and criteria, using judgment in making adaptations and modifications. Assignments have clear and specified objectives. This level requires developmental experience in a professional position or equivalent graduate-level education. Receives instruction on specific assignment objectives, complex features, and possible solutions. Assistance is furnished on unusual problems. Work is reviewed for application of professional judgment. May supervise or coordinate the work of drafters or technicians.

### ▶ Engineering Level 4 (GS-11 or Assistant Professor)

A fully competent engineer in the subject matter or the functional areas of the assignments. Plans and conducts work requiring judgment in the evaluation, selection, or adaptation or modification of standard techniques, procedures or criteria. Devises new approaches to problems. Requires professional experience to assure competence as a professional. For research positions, a doctoral degree may be substituted for experience. Independently performs assignments with instructions as to the general results expected. Receives technical guidance on unusual or complex problems and supervisory approval to projects. May supervise a few engineers or technicians on assigned work.

### ▶ Engineering Level 5 (GS 12 or Associate Professor)

Applies intensive and diversified knowledge of engineering principles and practices in broad areas of assignments. Makes decisions independently on engineering problems and methods, and represents the organization to resolve important questions. Requires the use of advanced techniques and the modification and extension of theories, precepts, and practices of own field and related sciences or disciplines. The knowledge and expertise required for this level usually results from progressive experience. Consults supervisor concerning unusual problems and developments. Supervises, coordinates, and reviews the work of a small staff of engineers and technicians. Estimates personnel needs, schedules and assigns work. As individual research or staff specialist, may be assigned to projects by others.

### ▶ Engineering Level 6 (GS 13 or Full Professor)

Technical responsibility for interpreting, organizing, executing, and coordinating assignments. Plans and develops engineering projects with unique or controversial problems which impact major company programs. Involves exploration of subject area, definition of scope and selection of problems for investigation, novel concepts and approaches. Maintains liaison with individuals and units within or outside the organization, with responsibility for acting independently on technical matters. Work at this level requires extensive progressive experience. Supervision received is administrative, with assignments given in terms of general objectives and limits. Plans, organizes and supervises the work of a staff of engineers and technicians. Evaluates progress and results obtained, recommends major changes to achieve objectives. As individual researcher or staff specialist, may be assisted on individual projects.

## ▶ Engineering Level 7 (GS 14 or Distinguished Professor or Academic Department Head)

Makes decisions and recommendations that are recognized as authoritative and have an important impact on extensive engineering activities. Initiates and maintains extensive contact with key engineers and officials of other organizations and companies, requiring skill in persuasion and negotiation of critical issues. Individuals must demonstrate creativity, foresight, and mature engineering judgment in anticipating and solving unprecedented engineering problems, program objectives, and requirements, organizing programs, and developing standards and guides for diverse engineering activities. Receives general administrative direction. Directs several subordinate supervisors or team leaders. As individual researcher and consultant, may be assisted on individual projects by other engineers and technicians.

## ▶ Engineering Level 8 (GS 15 or Academic Department Head or Dean)

Makes decisions and recommendations that are considered authoritative and have a far-reaching impact on extensive engineering and related activities of the company. Negotiates critical and controversial issues with top-level engineers and officers of other organizations and companies. Demonstrates a high degree of creativity, foresight, and importance. Receives general administrative direction. Supervises several subordinate supervisors or team leaders. As an individual researcher and consultant, may be assisted on individual projects by other engineers and technicians. NOTE: Individuals in charge of a company's engineering program may match any of several of these job levels depending on the size and complexity of the engineering problem. Excluded at Level 8, but included at Level 9, are engineers in charge of programs so extensive and complex that one or more supervisory engineers are performing at Level 8. Also excluded from Level 8 and included at Level 9 are individual researchers and consultants who are recognized as national/international authorities and scientific leaders in very broad areas of scientific interest and investigation.

## ▶ Engineering Level 9 (more than GS 15 or Academic Dean or higher)

Included in Level 9 are those engineers specifically excluded from Level 8, plus other engineers whose activities and responsibilities exceed those of the prior levels.

This information is from the Sloan Career Cornerstone Center web site

Note: Most resources in this section are provided by IEEE and the US Department of Labor, Bureau of Labor Statistics.

# Appendix B

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

| Stages of Growth | Typical Responsibilities-Autonomy-Judgment |
|---|---|
| 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 principles and techniques commonly employed in the specific narrow areas of assignments. |
| ENGINEER I/II<br>(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

Levels of Responsibilities in Creative Engineering Practice for Engineering
Leadership of Continuous Technology Development & Innovation
In Industry and Government Service

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### Senior Levels of Technology Leadership

**Position Title:**

Engineer IX (GS-18, 17, 16)
Chief Engineer / Vice President of Engineering & Technology

Engineer VIII (GS-15)
Director of Engineering

### Middle Levels of Technology Leadership

**Position Titles:**

Engineer VII (GS-14)
Department/Division Manager

Engineer VI (GS-13)
Technical Area Manager

### First Levels of Technology Leadership

**Position Titles:**

Engineer V (GS-12)
Senior Engineer/Principal Engineer/Project Leader/Group Leader

Engineer IV (GS-11)
Project Engineer/Process Engineer

Engineer III (GS-9)
Design/Development Engineer

### Entry Level Engineer

**Position Titles:**

Engineer II/I (GS-7, 5)
Entry Level Engineer

# Appendix D

System Summary of Skills and Professional Curricula Required for Early Career, Mid-Career and Senior Career Development in Engineering Practice for Leadership of Technology Development & Innovation in Industry

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**Early Career Development**

**From Entry Level Engineer I Thru Level IV Engineer**

**Leading to Professional Master of Engineering M.Eng. At Level IV Engineer**

**Project Level Core-Competence Skills**

- Systems Engineering
- Project Management
- Economic Issues of Technology Innovation
- Engineering Ethics Case Studies and Canons of Practice
- Communications for Project Leaders
- Six-Sigma for Continuous Innovation
- Leading Effective Technology Innovation - Needs finding; Team building
- Applied Engineering Statistics

- Planned Studies
- Creative Problem Solving – Technical Project Level (Technology Development Project)
- Self-Directed Learning - Growing from novice to expert at the cutting edge of a specific core technology (On-Job / Industry)
- Experiential Learning in Engineering Practice - Growing in experience & engineering judgment at project level in practice

**Mid-Career Development**

**From Level IV Engineer Thru Level VI Engineer**

**Leading to Professional Doctor of Engineering D. Eng. At Level VI Engineer**

**Program Level Core-Competence Skills**

- Systems Engineering Management
- Technical Program Management
- Creating Cultures for Innovation - Fostering Collaborative Creativity - Mentoring Champions
- Fostering Ethics and Decision Making
- Financial Issues of Technology Innovation
- Communications for Program Managers
- Emerging Technologies

- Planned Studies
- Creative Problem Solving – Technical Program Level (Technology Development Project)
- Self-Directed Learning - Growing from technical expert to expertise in technology leadership (On-Job / Industry)
- Experiential Learning in Engineering Practice - Growing in experience & engineering judgment at program level in practice

**Senior-Career Development**

**From Level VI Engineer Thru Level IX Engineer**

**Leading to Chief Engineer At Level IX Engineer**

**Policy Level Core-Competence Skills**

- Technology Policy Making
- Strategic Decision Making - Assessment of Core Areas for Technology Improvements and Breakthroughs
- Evaluation of Risk / Return
- Setting Corporate Engineering Ethics
- Communications for Policy Makers
- Corporate Financial Issues for Technology Innovation
- Building the Corporate Culture for Engineering Creativity and Innovation

- Planned Studies
- Creative Problem Solving – Technical Policy Level (Technology Development Project)
- Self-Directed Learning - Growing in breadth of leadership expertise for technology innovation (On-Job / Industry)
- Experiential Learning in Engineering Practice - Growing in experience & engineering judgment at policy level in practice

# Appendix E

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

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Needs → Engineering → Technology

↓↑

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

project

# Appendix F

## 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 the Chief Engineer / Vice President of Engineering & 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 & innovation

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

## Appendix G

# Functions of Creative Engineering Practice and Scientific Research

### Practice of Engineering

‘Creative Technology Development’

… The role of needs-driven systematic technological development in industry and government is the purposeful invention [design] and innovation of new or improved concepts, techniques, materials, devices, products, or systems and manufacturing processes. Its aim is to meet the hopes, wants, and needs of society, through change towards its general betterment, brought about by engineering development. It is creative and non-repetitive work and ranges from exploratory development, with concept and invention, through the experimental phases of feasibility to the advanced development and design of production prototypes and introduction into manufacture or operations. The primary base of needs-driven technological development is the conceptual ideas of men and women to bring about needed change for the benefit of mankind.

“Technology does not exist to serve itself. It is there to work for people – to improve the way they live, to safeguard their health, to preserve their environment (GE)” By technology, we refer to any “systematic, organized body of applicable interrelated concepts and ideas that is rational and valid enough to stand up under the test of experimental demonstration and experimental validation, and represents a common experience regardless of the society or nation in which it is observed (Alstadt).”

### Practice of Scientific Research

‘Basic’ and ‘Applied Research’

… The role of basic (fundamental) research in industry and government is the pursuit of new knowledge within specific fields of interest, which could be of potential use to the future business of the organization. Its aim is to discover and to gain a better understanding of phenomena through creative in-depth investigation at the frontiers of a scientific discipline. The results will extend the existing body of scientific knowledge useful to the organization in the future.

… The role of applied (directed-strategic) research in industry and government is the strategic pursuit of new knowledge in specific areas in direct support of development projects within the organization. Its primary aim is to discover, understand, and describe new physical phenomena useful to the understanding of specific phenomena anticipated or uncovered during the course of a technology development project. The results of this in-depth investigation and analysis will extend the existing body of scientific knowledge with committed use for the organization.

A secondary purpose is to provide technical consultation to other divisions of the organization whenever the existing body of specialized knowledge within the research group is needed for immediate problems.