ENABLING A STRONG U.S. ENGINEERING WORKFORCE FOR
LEADERSHIP OF TECHNOLOGY DEVELOPMENT AND INNOVATION IN
INDUSTRY: CRITICAL SKILL-SETS FOR MID-CAREER DEVELOPMENT
LEADING TO THE PROFESSIONAL DOCTOR OF ENGINEERING

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Enabling a Strong U.S. Engineering Workforce for Leadership of Technology Development and Innovation in Industry: Critical Skill-Sets for Mid-Career Development Leading to The Professional Doctor of Engineering

1. Introduction

This is the third 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 describes the critical innovation skills, knowledge, qualifications, and experience factor that is required for mid-career development of engineers for effective engineering leadership of continuous technology development and innovation in industry at the technical program management level. It describes the framework and an integrative educational approach concurrent with engineering practice leading to the professional Doctor of Engineering for responsible engineering leadership of systematic technology development and innovation.

2. Professional Education for Engineers – The New Challenge for Industrial Innovation

While the U.S. system of graduate education continues to set the world standard and sustains the preeminence of the U.S. scientific workforce for basic research at the universities, the National Collaborative Task Force is leading a major reform in professionally oriented engineering graduate education to enhance the innovative capacity of the U.S. engineering workforce in industry to retain U.S. preeminence in engineering practice for technology development and innovation to enhance competitiveness.

2.1 The Modern Practice of Engineering for Leadership of the Continuous Technology Development & Innovation Process in Industry

A new paradigm of the practice of engineering for the creation (invention), design, development, and innovation of new/improved/breakthrough technology has emerged which is substantially different from that portrayed by science policy of 1945 for the development of technology. The reform of professional engineering graduate education is 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 of engineering (Appendix A).
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 conceptualization of new ideas and concepts to meet real-world needs of people, engineers actually obsolete existing technology through their improvements and deliberate breakthroughs.

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. Rather, creative engineering projects in industry frequently drive the need for directed strategic research efforts at universities when necessary or anticipated in order to gain a better understanding of the natural phenomena involved.

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 through responsible leadership. Engineering practice and its resulting outcome technology have been redefined for the 21st century. 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.” As Educating the Engineer for 2020: Phase II Report points out:

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

2.2 Modern Practice of Engineering for Technology Development & Innovation Mandates Reform of Professional Graduate Education for U.S. Engineering Workforce 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.

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.
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.

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 leaning 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. Professional Education for Innovation — Leading to the Professional Doctor of Engineering

The National Collaborative Task Force recognizes that educating engineers as innovators and leaders is not a one time event. Rather, professional education is a process that extends throughout the engineer’s professional career. Educating professionals does not terminate at the undergraduate entry level, or at the professional master’s level, or at the professional doctoral level.

4.1 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 is to further the development of the experienced practicing engineer beyond entry level to his or her fullest creative, innovative, and leadership potential at the highest levels of professional responsibility of engineering practice.
4.2 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

4.3 Mid-Career Development of Engineers —
Beyond the Professional Master’s Level for Innovation in Engineering Practice

As the National Academy of Engineering report, Educating the Engineer of 2020, points out:
“The future engineering curriculum should be built around developing skills and not around
teaching available knowledge. We must focus on shaping analytic skills, problem-solving skills,
and design skills. We must teach future engineers to be creative and flexible, to be curious and
imaginative.”

The Task Force believes that at the graduate level of engineering practice, the critical skills must
include innovation and professional engineering leadership. Mastery of these skills at Level VI
Engineer is the objective of the integrative program of study leading to the professional Doctor
of Engineering (Appendix B,C, and D). Reinventing engineering education at the graduate level
for creative professional practice requires not only change with increased emphasis toward a
professionally oriented curriculum for innovation but also change with increased emphasis on a
new educational process that supports the practice of engineering for innovation. This change
must support the maturation characteristics of emerging innovators /leaders, and the manner by
which experienced practitioners learn, grow, and develop in creating, technology (Appendix E).
5. Conclusions: A Work in Progress —
To Enhance the U.S. Engineering Workforce for Competitiveness

The modern practice of engineering for technology development and innovation has changed substantially from that portrayed by 1945 science policy. Subsequently, the paradigm shift that has occurred in the practice of engineering for technology development and innovation in industry mandates a different type of professional curriculum and approach than that which has emerged for the graduate education of the nation’s scientists for scientific research. Whereas the United States has built a world-class infrastructure for basic scientific research and a system of graduate education envied in other countries since 1945, it is time for the United States to place an equal investment and educational emphasis for U.S. engineering workforce development in industry. The United States must increase its commitment and investment in the advancement of professional education for development of the U.S. engineering workforce in industry which will directly optimize the U.S. economy for global competitiveness and productive innovation. Investing in the development of the U.S. engineering workforce for innovation in industry is critical in retaining U.S. technological leadership.

The work of the Task Force is a work in progress. Its recommendation are based on two guiding tenets. First, our technological progress requires an experienced, well-educated U.S. engineering workforce that is further 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. 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.

Bibliography

Appendix A

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

Needs → Engineering → Technology

Directed Scientific Research to gain a better understanding of phenomena when needed or anticipated during the technology development project.
## Appendix B -1

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

<table>
<thead>
<tr>
<th>Stages of Growth</th>
<th>Typical Responsibilities-Autonomy-Judgment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGINEER IX</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER VIII</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER VII</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER VI</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER V</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER IV</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER III</td>
<td>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.</td>
</tr>
<tr>
<td>ENGINEER I/II</td>
<td>Requires knowledge and application of known laws and data. Using prescribed methods, applies standard practices/techniques under direction of an experienced Engineer.</td>
</tr>
</tbody>
</table>
Appendix: B - 2

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

Top 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: B - 2

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

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 B - 3

A Comparison between Career Paths that Support Academic Research at Universities and those that Support Engineering Practice for Innovative Technology Development in Industry and Government Service

<table>
<thead>
<tr>
<th>Industry/Government (Technology Development)</th>
<th>Universities (Academic Research)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Senior Executive Levels</strong></td>
<td><strong>Senior Executive Levels</strong></td>
</tr>
<tr>
<td>Engineer IX (GS-18, 17,16)</td>
<td>Senior Executive Levels</td>
</tr>
<tr>
<td>Vice President of Engineering and Technology</td>
<td>Dean of Engineering/Technology</td>
</tr>
<tr>
<td><strong>Executive Engineer Levels - Technology Leadership</strong></td>
<td><strong>Administrative Academic Levels</strong></td>
</tr>
<tr>
<td>Engineer VIII (GS-15)</td>
<td>Department Head</td>
</tr>
<tr>
<td>Director of Engineering</td>
<td></td>
</tr>
<tr>
<td>Engineer VII (GS-14)</td>
<td>Distinguished Professor</td>
</tr>
<tr>
<td>Department/Division Manager</td>
<td></td>
</tr>
<tr>
<td>Engineer VI (GS-13)</td>
<td>Professor</td>
</tr>
<tr>
<td>Technical Area Manager</td>
<td></td>
</tr>
<tr>
<td><strong>Senior Engineer/Project Management Levels</strong></td>
<td><strong>Senior Research Specialist Levels</strong></td>
</tr>
<tr>
<td>Engineer V (GS-12)</td>
<td>Associate Professor</td>
</tr>
<tr>
<td>Senior/Principal Engineer/Project Leader/Group Leader</td>
<td></td>
</tr>
<tr>
<td>Engineer IV (GS-11)</td>
<td>Assistant Professor (PhD)</td>
</tr>
<tr>
<td>Project Engineer/Process Engineer</td>
<td></td>
</tr>
<tr>
<td>Engineer III (GS-9)</td>
<td>Post-Doctorate in Research</td>
</tr>
<tr>
<td>Design/Development Engineer</td>
<td></td>
</tr>
<tr>
<td><strong>Entry Level in Engineering Practice</strong></td>
<td><strong>Entry Level in Academic Research</strong></td>
</tr>
<tr>
<td>Engineer II/I (GS-7, 5)</td>
<td>Graduate Research Assistant</td>
</tr>
<tr>
<td>Entry Level Engineer/Engineer-in-Training</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B - 4

Professional Characteristics, Leadership Responsibilities, And Growth Levels in Engineering Practice – (NSPE)

Engineer IX

Equivalent Federal General Schedule Grade
Senior Executive Service GS - 18, 17, 16

**General Characteristics.** An engineer in this level is either: 1) in charge of programs so extensive and complex as to require staff and resources of sizable magnitude (e.g., research and development, a department of government responsible for extensive engineering programs, or the major components of an organization responsible for the engineering required to meet the objectives of the organization); or 2) is an individual researcher or consultant who is recognized as a national and/or international authority and leader in an area of engineering or scientific interest and investigation.

**Typical Position Titles.** Director of Engineering, General Manager, Vice President, President, Partner, Dean, Director of Public Works

**Education.** Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

**Licensure Status.** Licensed Professional Engineer

**Typical Professional Attainments.** Member of Professional Society (Member Grade), Member of Technical Societies (Member Grade); Publishes engineering papers, articles, textbooks
Engineer VIII

Equivalent Federal General Schedule Grade
GS-15

General Characteristics. Make decisions and recommendations that are recognized as 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. Individuals at this level demonstrate a high degree of creativity, foresight, and mature judgment in planning, organizing and guiding extensive engineering programs and activities of outstanding novelty and importance.

Direction Received. Receives general administrative direction

Typical Duties & Responsibilities. One or both of the following: 1) In a supervisory capacity is responsible for a) an important segment of a very extensive and highly diversified engineering program, or b) the entire engineering program when the program is of moderate scope. The programs are of such complexity that they are of critical importance to overall objectives, include problems of extraordinary difficulty that often have resisted solution and consist of several segments requiring subordinate supervisors. Is responsible for deciding the kind and extent of engineering and related programs needed for accomplishing the objectives of the organization, for choosing the scientific approaches, for planning and organizing facilities and programs, and for interpreting results; 2) As individual researcher and consultant, formulates and guides the attack on problems of exceptional difficulty and marked importance to the organization or industry. Problems are characterized by their lack of scientific precedents and source material, or lack of success of prior research and analysis so that their solution would represent an advance of great significance and importance. Performs advisory and consulting work for the organization as a recognized authority for broad program areas or in an intensely specialized area of considerable novelty and importance.

Responsibility For Direction of Others. Supervises several subordinate supervisors or team leaders, some of whose positions are comparable to Engineer VII, or individual researchers some who whose positions are comparable to Engineer VII. As an individual researcher and consultant may be assisted on individual projects with other engineers and technicians.

Typical Position Titles. Chief Engineer, Bureau Engineer, Director of Research, Department Head or Dean, County Engineer, City Engineer, Director of Public Works, Senior Fellow, Senior Staff, Senior Advisor, Senior Consultant, Engineering Manager.

Education. Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

Licensure Status. Licensed Professional Engineer

Typical Professional Attainments. Member of Professional Society (Member Grade), Member of Technical Societies (Member Grade); Publishes engineering papers, articles, textbooks
Engineer VII

Equivalent Federal General Schedule Grade
GS-14

**General Characteristics.** Make decisions and recommendations that are recognized as authoritative and have an important impact on extensive engineering activities. Initiates and maintains extensive contacts with key engineers and officials of other organizations and companies, requiring skill in persuasion and negotiation of critical issues. At this level individuals will have demonstrated creativity, foresight, and mature engineering judgment in anticipating and solving unprecedented engineering problems, determining program objectives and requirements, organizing programs and projects, and developing standards and guides for diverse engineering activities.

**Direction Received.** Supervision received is essentially administrative with assignments given in terms of broad general objectives and limits.

**Typical Duties & Responsibilities.** One or both of the following: 1) in a supervisory capacity is responsible for a) an important segment of the engineering program of an organization with extensive and diversified engineering requirements, or b) the entire engineering program of an organization when it is more limited in scope. The overall engineering program contains critical problems the solution of which requires major technological advances and opens the way for extensive related development. The extent of responsibilities generally requires several subordinate organizational segments or teams. Recommends facilities, personnel, and funds required to carry out programs which are directly related with and directed toward fulfillment of overall organization objectives; 2) As individual researcher and consultant is a recognized leader and authority in the organization in a broad area of specialization or in a narrow but intensely specialized field. Selects research problems to further the organization's objectives. Conceives and plans investigations of broad areas of considerable novelty and importance for which engineering precedents are lacking in areas critical to the overall engineering program. Is consulted extensively by associates and others with a high degree of reliance placed on the scientific interpretations and advice. Typically, will have contributed inventions, new designs, or techniques which are regarded as major advances in the field.

**Responsibility For Direction of Others.** Directs several subordinate supervisors or team leaders, some of whom are in a position comparable to Engineer VI, or as individual researcher and consultant, may be assisted on individual projects by other engineers and technicians.

**Typical Position Titles.** Principal Engineer, Division or District Engineer, Department Manager, Director or Assistant Director of Research, Consultant, professor, Distinguished Professor or Department Head, Assistant Chief or Chief Engineer, City or County Engineer.

**Education.** Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

**Licensure Status,** Licensed Professional Engineer

**Typical Professional Attainments.** Member of Professional Society (Member Grade), Member of Technical Societies (Member Grade); Publishes engineering papers, articles, textbooks
Engineer VI

Equivalent Federal General Schedule Grade GS-13

General Characteristics. Has full technical responsibility for interpreting, organizing, executing, and coordinating assignments. Plans and develops engineering projects concerned with unique or controversial problems which have an important effect on major organization programs. This involves exploration of subject area, definition of scope and selection of problems for investigation and development of novel concepts and approaches. Maintains Liaison with individuals and units within or outside the organization with responsibility for acting independently on technical matters pertaining to the field. Work at this level usually requires extensive progressive experience.

Direction Received. Supervision received is essentially administrative, with assignments given in terms of broad general objectives and limits.

Typical Duties & Responsibilities. One or more of the following: 1) in a supervisory capacity a) plans, develops, coordinates, and directs a number of large and important projects or a project of major scope and importance; or b) is responsible for the entire engineering program of an organization when the program is of limited complexity and scope. The extent of his or her responsibilities generally requires a few (3 to 5) subordinate supervisors or team leaders with at least one in a position comparable to level V; 2) As individual researcher or worker conceives, plans and conducts research in problem areas of considerable scope and complexity. The problems must be approached through a series of complete and conceptually related studies, are difficult to define, require unconventional or novel approaches, and require sophisticated research techniques. Available guides and precedents contain critical gaps, are only partially related to the problem or may be largely lacking due to the novel character of the project. At this level, the individual researcher generally will have contributed inventions, new designs, or techniques which are of material significance in the solution of important problems; 3) As a staff specialist serves as the technical specialist for the organization (division or company) in the application of advanced theories, concepts, principles, and processes for an assigned area of responsibility (i.e. subject matter, function, type of facility or equipment, or product). Keeps abreast of new scientific methods and developments affecting the organization for the purpose of recommending changes in emphasis of programs or new programs warranted by such developments.

Responsibility For Direction of Others. Plans, organizes, and supervises the work of a staff of engineers and technicians. Evaluates progress of the staff and results obtained and recommend major changes to achieve overall objectives. Or, as individual research or staff specialist may be assisted on individual projects by other engineers or technicians.

Typical Position Titles. Senior or Principal Engineer, Division or District Engineer, Production Engineer, Assistant Division, District or Chief Engineer, Consultant, Professor, City or County Engineer.

Education. Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

Licensure Status. Licensed Professional Engineer

Typical Professional Attainments. Member of Professional Society (Member Grade).Member of Technical Societies (Member Grade); Publishes engineering papers, articles, textbooks
Engineer V

Equivalent Federal General Schedule Grade
GS-12

**General Characteristics.** Applies intensive and diversified knowledge of engineering principles and practices in broad areas of assignments and related fields. Make decisions independently on engineering problems and methods, and represents the organization in conferences to resolve important questions and to plan and coordinate work. Requires the use of advanced techniques and the modifications and extension of theories, precepts and practices of the field and related sciences and disciplines. The knowledge and expertise required for this level of work usually result from progressive experience.

**Direction Received.** Supervision and guidance relate largely to overall objectives, critical issues, new concepts, and policy matters. Consults with supervisor concerning unusual problems and developments.

**Typical Duties & Responsibilities.** One or more of the following: 1) In a supervisory capacity, plans, develops, coordinates, and directs a large and important engineering project or a number of a small projects with many complex features. A substantial portion of the work supervised is comparable to that described for engineer IV; 2) As individual researcher or worker, 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 improved techniques and procedures. Work is expected to result in the development of new or refined equipment, materials, processes, products, and/or scientific methods; 3) As staff specialist, develops and evaluates plans and criteria for a variety of projects and activities to be carried out by others. Assesses the feasibility and soundness of proposed engineering evaluation tests, products, or equipment when necessary data are insufficient or confirmation by testing is advisable. Usually performs as a staff advisor and consultant as to a technical specialty, a type of facility or equipment, or a program function.

**Responsibility For Direction of Others.** Supervises, coordinates, and reviews the work of a small staff of engineers and technicians, estimates personnel needs and schedules and assigns work to meet completion date. Or, as individual researcher or staff specialist may be assisted on projects by other engineers or technicians.

**Typical Position Titles.** Senior or Principal Engineer: Resident, Project, Office, Design, Process, Research, Assistant Division Engineer, Associate Professor, Project Leader.

**Education.** Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

**Licensure Status.** Licensed Professional Engineer

**Typical Professional Attainments.** Member of Professional Society (Member Grade), Member of Technical Societies (Member Grade); Publishes engineering papers, articles, textbooks
Engineer IV

Equivalent Federal General Schedule Grade
GS-11

**General Characteristics.** As a fully competent engineer in all conventional aspects of the subject matter of the functional area of the assignments, plans and conducts work requiring judgment in the independent evaluation, selection, and substantial adaptation and modification of standard techniques, procedures, and criteria. Devises new approaches to problems encountered. Requires sufficient professional experience to assure competence as a fully trained worker, or, for positions primarily of a research nature, completion of all requirements for a doctoral degree may be substituted for experience.

**Direction Received.** Independently performs most assignments with instructions as to the general results expected. Receives technical guidance on unusual or complex problems and supervisory approval on proposed plans for projects.

**Typical Duties & Responsibilities.** Plans, schedules, conducts, or coordinates detailed phases of the engineering work in a part of a major project or in a total project of moderate scope. Performs work which involves conventional engineering practice but may include a variety of complex features such as conflicting design requirements, unsuitability of conventional materials, and difficult coordination requirements. Work requires a broad knowledge of precedents in the specialty area and a good knowledge of and practices of related specialties.

**Responsibility For Direction of Others.** May supervise or coordinate the work of engineers, drafters, technicians, and others who assist in specific assignments.

**Typical Position Titles.** Engineer or Assistant Engineer, Resident, Project, Plant, Office, Design, Process, Research, Chief Inspector, Assistant Professor.

**Education.** Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

**Licensure Status.** Licensed Professional Engineer

**Typical Professional Attainments.** Member of Professional Society (Member Grade), Member of Technical Societies (Associate Grade or Equivalent)/Member of Technical Societies (Member Grade); Publishes engineering papers, articles, text books
Engineer III

Equivalent Federal General Schedule Grade
GS-9

General Characteristics. Independently evaluates, selects, and applies standard engineering techniques, procedures, and criteria, using judgment in making minor adaptations and modifications. Assignments have clear and specified objectives and require the investigation of a limited number of variables. Performance at this level requires developmental experience in a professional position or equivalent graduate level education.

Direction Received. Receives instructions on specific assignment objectives, complex features, and possible solutions. Assistance is furnished on unusual problems and work is reviewed for application of sound professional judgment.

Typical Duties & Responsibilities. Performs work which involves conventional types of plans, investigations, surveys, structures, or equipment with relatively few complex features for which there are precedents. Assignments usually include one or more of the following: Equipment design and development, test of materials, preparation of specifications, process study, research investigations, report preparation, and other activities of limited scope requiring knowledge of principles and techniques commonly employed in the specific narrow area of assignments.

Responsibility For Direction of Others. May supervise or coordinate the work of drafters, technicians, and others who assist in specific assignments.

Typical Position Titles. Engineer or Assistant Engineer, Project, Plant, Office, Design, Process, Research, Chief Inspector, Assistant Professor

Education. Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

Licensure Status. Certified Engineer Intern/Licensed Professional Engineer

Typical Professional Attainments. Member of Professional Society (Associate Grade/Member Grade), Member of Technical Societies (Associate Grade or Equivalent)
Engineer I/II

Equivalent Federal General Schedule Grade
GS- 5, 7

**General Characteristics.** This is the entry level for professional work. Performs assignments designed to develop professional works knowledge and abilities, requiring application of standard techniques, procedures, and criteria in carrying out a sequence of related engineering tasks. Limited exercise of judgment is required on details of work and in making preliminary selections and adaptations of engineering alternatives.

**Direction Received.** Supervisor screens assignments for unusual or difficult problems and selects techniques and procedures to be applied on non-routine work. Receives close supervision on new aspects of assignments.

**Typical Duties & Responsibilities.** Using prescribed methods, performs specific and limited portions of a broader assignment of an experienced engineer. Applies standard practices and techniques in specific situations, adjusts and correlates data, recognizes discrepancies in results, and follows operations through a series of related detailed steps or processes.

**Responsibility For Direction of Others.** May be assisted by a few aides or technicians.

**Typical Position Titles.** Junior Engineer, Associate Detail Engineer, Engineer-in-Training, Assistant Research Engineer, Construction Inspector.

**Education.** Bachelor's Degree in engineering from an ABET accredited curriculum, or equivalent, plus appropriate continuing education.

**Licensure Status.** Certified Engineer Intern/Engineering-In-Training

**Typical Professional Attainments.** Member of Professional Society (Associate Grade), Member of Technical Societies (Associate Grade or Equivalent)
Appendix C

Progressive Critical Skill-Set, Knowledge, and Experience Required in Engineering Practice for Leadership of Technology Development And Innovation in Industry and Government Service

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Core Qualifications - Senior Executive Engineer Levels

Top Levels of Corporate Technology Leadership

Engineers at the top levels of corporate technology leadership act in responsible charge for defining the core character, mission, vision, goals, and objectives of the technology-based organization; for setting responsible technology policy; for building an organizational culture that fosters a core value system of ethical responsibility; for planning, staffing, organizing, and allocating financial, professional, and material resources to enhance the organization’s overall technological thrust; and for building an innovative culture that continually fosters the organization’s core competence and innovative capacity for constant technology development and innovation such that industrial creativity and innovation can flourish to sustain the organization’s competitive advantage responsive to customer needs.

Engineer IX (GS-18,17,16) 20+ years of progressive experience
Vice President of Engineering and Technology

Critical Skills-Set, Knowledge, and Experience Required as Defined by Tasks and Responsibilities of Engineering Practice and Technology Leadership:

- Broad overall knowledge of corporate systems technology
- External awareness of competitive technology
- Strategic vision
- Leading change
- Leading people
- Results driven
- Business acumen
- Building coalitions/communications
- Technology policy making
- Ethical value judgment
- Integrity
Core Qualifications - Executive Engineer Levels

Third Level of Technology Leadership

Engineers at the third level of corporate technology leadership act in responsible charge for defining, planning, organizing, integrating, and leading the overall technological development of new or improved large scale/complex programs, systems, or operations responsive to corporate objectives, goals, vision and mission of the technology-based organization.

Engineer VIII (GS-15) 20+ years of progressive experience
Director of Engineering

Engineer VII (GS-14) 15+ years of progressive experience
Department/Division Manager

Critical Skills-sets, Knowledge, and Experience Required as Defined by Tasks and Responsibilities of Engineering Practice and Technology Leadership:

- Expert knowledge of corporate systems technology
- Broad understanding of emerging sciences relevant to organization’s technological thrust
- Leading major systems engineering and cross functional teams
- Financial management/understanding of the economics of technology development and innovation
- Human resources management and development of engineering profession
- Organizational development of innovative cultures for technology development
- Corporate decision analysis/decision making for innovative technology programs
- Value judgment and ethical decision-making regarding safety issues, environmental issues, understanding systems failures, and prevention
- Mentoring of creative professionals for future leadership positions
Core Qualifications - Senior Engineer/Project Management Levels

Second Level of Technology Leadership

Engineers at the second level of corporate technology leadership act in responsible charge for defining, planning, organizing, integrating, and leading the development and innovation of large-scale complex programs within functional technological areas.

Engineer VI (GS-13)  12+ years of progressive experience
Functional Area Manager

Engineer V  (GS-12)  9+ years of progressive experience
Senior Engineer/Principal Engineer/Project Leader/Group Leader

Critical Skills-Sets, Knowledge, and Experience Required as Defined by Tasks and Responsibilities of Engineering Practice and Technology Leadership:

- Expert knowledge of functional area technology
- Core systems engineering and multidisciplinary thinking with responsible charge
- Needs-finding and identification of problems/opportunities for technology program-making
- Innovative thinking and strategic vision for program development planning from phases of conceptual exploratory development through advanced engineering development, and recognizing the need for directed research to gain a better understanding of anticipated or unknown phenomenon during technology development programs
- Contracting processes and regulations
- Project leadership and tracking
- Teambuilding
- Coaching of creative professionals
- Customer orientation
- Quality focus
Core Qualifications – Project Engineer Levels

First Levels of Technology Leadership

Engineers at the first levels of corporate technology leadership are fully competent engineering professionals and act in responsible charge for development and innovation of new or improved components of a subsystem or project.

Engineer IV (GS-11) 7+ years of progressive experience
Project Engineer/Process Engineer

Engineer III (GS-9) 5+ years of progressive experience
Design/Development Engineer

Critical Skills-Sets, Knowledge, and Experience Required as Defined by Tasks and Responsibilities of Engineering Practice and Technology Leadership:

- Expert knowledge of core project technology/process technology/product technology
- Competency in engineering method for systematic technology development and innovation
- Creative problem solving for innovative solutions to open-ended problems/opportunities
- Ethical judgment relevant to safety issues and environmental issues
- Engineering-technical judgment
- Project engineering
- Communication
- Critical thinking
- Self-directed learning
Core Qualifications - Entry Level Engineer

Entry Level– Trainee Level

Engineers at the entry-level of technology responsibility work at the level of known laws and data under close supervision of an experienced engineer on specific and limited portions of a broader assignment using prescribed methods, standard techniques, and procedures.

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

Critical Skills-sets, Knowledge, and Experience Required as Defined by Tasks and Responsibilities of Engineering Practice and Technology Leadership:

- Graduate of ABET approved program in engineering or technology
- Initiative, enthusiasm, ability to work well with others, and high growth potential for technology development and leadership of innovation in industry
- Attainment of ABET requirements at the basic educational level for entry into engineering practice
  a) an ability to apply knowledge of mathematics, science, and engineering
  b) an ability to design and conduct experiments, as well as to analyze and interpret data
  c) an ability to design a system, component, or process to meet desired needs
  d) an ability to function on multi-disciplinary teams
  e) an ability to identify, formulate, and solve engineering problems
  f) an understanding of professional and ethical responsibility
  g) an ability to communicate effectively
  h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
  i) a recognition of the need for, and an ability to engage in lifelong learning
  j) a knowledge of contemporary issues
  k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
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

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 Cannons of Practice
• Communications for Project Leaders
• Six-Sigma for Continuous Innovation
• Leading Effective Technology Innovation - Needs finding; Team building
• Applied Engineering Statistics

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

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 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

• 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

• 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 - 1

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

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

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

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

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

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

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

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

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

Target market for professional Doctor of Engineering programs

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

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

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

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

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

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

e) Professional D.Eng. programs should be specifically designed to be concurrent with engineering practice and should build upon six major integrative ingredients. These include:
   (1) Knowledge and skill-sets acquired by undergraduate and master’s education in engineering.
   (2) The engineer’s already established competency base in a technological field in industry.
   (3) On-going experiential-based learning in creative engineering practice.
   (4) Self-directed learning necessary to gain technological expertise in the practitioner’s field.
   (5) Project-based learning in substantive technology development project work.
   (6) Planned professional core studies and electives concurrent with practice.

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

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

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

c) Technology projects should yield new “ideas and concepts” for creative engineering solutions through proof of feasibility for new technological improvements, developments, and innovations for products, processes, systems, and technical operations or organizational infrastructure that ultimately contribute to the body of new technological knowledge of benefit to the advancement of engineering practice, the participant’s corporate sponsor, and society as a result of this deliberate creative engineering work for constant innovation.
d) Technology development projects will be of a directed nature resulting in a project report and a quality tangible experience of meaningful significance that is directly relevant to the technology development and innovation needs of the participant’s sponsoring industry/or society. This professional work should represent creation, improvement, development and innovation at the technical program leadership level wherein the participant is in responsible charge.

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

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

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

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

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

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

- **Entrance requirements**

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

  - Because many of the skill-sets that are required during the professional maturation process in engineering practice for senior leadership of technology development & innovation in industry can only be attained through progressive practical experience, it is recommended that a minimum of at least five to ten years of progressive professional experience in engineering practice, beyond entry-level, plus the professional M.Eng. should be required for entrance into these professionally-oriented graduate programs. Completion of the PE is also recommended when appropriate.
Appendix: E - 2

Framework: For High Quality Postgraduate Professional Education Leading to The Professional Doctor of Engineering that is Integrative with Practice and Enables Lifelong learning and Professional Development of Engineers as Creative Professionals and Technology Leaders in Industry

Professional Doctor of Engineering — For Creative Engineering Practice & Leadership
Level VI Engineer - Skill-Sets / Outcomes

Focus: Professional Development of Experienced Engineer-Leaders in Industry
For Creative Technology Development and Innovation at Program Leadership Level

Postgraduate Professional Education Integrative with Creative Engineering Practice

12 Credit Hours  Core Professional Courses
Emphasis on the professional dimensions / knowledge / critical skill-sets required in advanced engineering practice (Level VI Engineer) for engineering leadership, professional responsibility, and creative problem solving at technical program level for technology development and innovation in industry/government service.
(Four Professional Courses)

6 Credit Hours  Professional Electives
Emphasis on flexibility in tailoring the program electives to be relevant to the participant’s field of technology or other professional needs to be selected by the participant with approval of oversight committee; including self-directed learning and independent study in special topics, as well as formal courses/modules.
(Two Elective Courses)

12 Credit Hours  Directed Technology Development Project
Emphasis on gaining real-world experience in creative problem-solving through project-based (problem-centered learning) focusing on innovation through a quality tangible experience of meaningful significance that is directly relevant to the technology development & innovation needs of the participant’s sponsoring industry. This work should represent significant innovative development e.g. at the technical program leadership level wherein the participant is in responsible charge at (Level VI Engineer).

30 Credit Hours
Appendix: E - 3

Components: For High-Quality Postgraduate Professional Education Leading to the Professional Doctor of Engineering that are Integrative with Practice and Enable Lifelong learning and Professional Development of Engineers as Creative Professionals and Technology Leaders in Industry

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

Focus: Professional Development of Experienced Engineer-Leaders in Industry
For Creative Technology Development and Innovation at Program Leadership Level

Integrative Components:

- Curricular Components
  - 12 cr. Core Professional Modules
  - 6 cr. Elective Modules
  - 12 cr. Technology Development Project
    In Industry (Focus on Innovation)

  - 30 cr. Total

- Professional Maturation Components
  a) Residency Component
     Full-time employment in engineering practice in industry/government service
  b) Progressive Experience Component Beyond Entry-Level
     Minimum of ten years of progressive experience beyond entry-level in engineering practice
  c) Technical Competency Component
     Demonstrated growth from competent professional to expert in a specific technological field

- Admission Requirements to Program
  Holder of the professional Master of Engineering (M.Eng.) degree or equivalent; ten years of progressive experience in engineering practice beyond entry-level; Level IV Engineer; plus strong letters of recommendation from participant’s sponsor / practicing professionals in engineering; and PE when appropriate.
Appendix: F

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

Professional Education for Engineers –

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

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

Data from the United States Bureau of Labor Statistics:

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

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

GUIDELINES FOR NATIONAL COLLABORATIVE TASK FORCE

➢ Focus on innovation and leadership

➢ Focus on development of U.S. Engineering Workforce for innovative competitiveness in industry, second to none in the world

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

  Council on Competitiveness

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

  Council on Competitiveness

➢ Create a new, innovative professional curriculum combined with engineering practice that matches and supports the progressive core-competence skills required for effective engineering leadership of technology development & innovation in industry — from beginning Entry Level Engineer through 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