Issues Driving Reform of Faculty Reward Systems to Advance Professional Graduate Engineering Education: Expectations For Core Professional Faculty


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Abstract

This is the fourth paper in the special panel session focusing on issues driving reform of faculty reward systems to advance professional engineering education for creative engineering practice and leadership of technological innovation to enhance U.S. competitiveness. This paper explores the conceptual beginnings of a template for improved faculty reward systems that better reflect the practice of engineering for full-time, tenure track professionally oriented faculty in schools of engineering and technology.

1. Background and History

The United States has built an excellent system of research-oriented graduate education that is second to none for the education of future engineering faculty and scientific researchers, and an excellent system of undergraduate education as preparation for entry into engineering practice, nevertheless a major reform in the U.S. system of engineering graduate education in context, organization, and culture to build complementary graduate programs of an advanced professional nature that enhance creative engineering practice for technology development and leadership of innovation in industry is needed.

Since implementation of the Vannevar Bush report (Science: The Endless Frontier) of 1945, which was followed by increased federal funding to accelerate the advancement of science, the nation’s schools of engineering have placed an increased emphasis on high-quality graduate education for academic scientific research. During this same time period, however, U.S. engineering education has not placed similar emphasis on high-quality professionally oriented graduate education for creative engineering practice and leadership of technology development and innovation in industry. Engineering graduate education in the United States has emerged primarily as a byproduct of academic scientific research, yielding organizational cultures and faculty reward systems that predominantly support the pursuit of academic scientific research.

2. Urgency for Reform of Professional Engineering Education for Practice

There is growing national awareness that the urgency for reform of engineering education exists not only at the basic level of undergraduate engineering education (as preparation for entry into engineering practice), but also at the advanced level of professional graduate engineering education to further the lifelong learning, growth, and development of graduate engineers after entry into engineering practice in industry. The ASEE Corporate Members Council and the Graduate Studies Division have established a National Collaborative Task Force for Engineering Graduate Education Reform to answer this call for reform of graduate engineering education, to better meet the needs of working engineers in industry, to stimulate technology innovation, and to enable a strong U.S. engineering workforce for competitiveness.
A major deficiency currently exists in the system of U.S. engineering graduate education which is affecting the nation’s innovative capacity for economic competitiveness. It is now evident that while U.S. science policy placed increased emphasis on academic scientific research as the primary driver and source of U.S. technological advancement during the 1960’s, 70’s, 80’s, and 90’s, that the 1945-linear research-driven model of engineering innovation is inadequate to ensure U.S. competitiveness. As a result of over four decades of neglect at the postgraduate level, the U.S. engineering workforce in industry has been underdeveloped for creative engineering practice and leadership of new/improved technological innovation for economic competitiveness and the nation’s defense.

Fundamental changes have occurred in the U.S. Science and Technology (S&T) innovation system with regard to the technological innovation process itself. A new model of purposeful, creative, and systematic needs-driven engineering development and innovation has emerged that is quite different from the linear, sequential research-driven model of engineering innovation portrayed by the 1945-linear research-driven paradigm of engineering practice. Scientific research and engineering practice are no longer viewed as linear sequential activities but rather as concurrent activities with unique missions, functions, and talents of those practitioners who engage in these two very different pursuits.

But after building organizational cultures for academic scientific research at the nation’s engineering schools and a belief system during the last four decades that academic scientific research is the primary source of U.S. technology innovation, along with building faculty reward systems that predominantly reward federally funded research, it has become extremely difficult for many university faculty and administrators to undergo required change and to reflect the modern process of purposeful, systematic engineering innovation for needs-driven technology development. Among the issues that William Wulf, president of the National Academy of Engineering, pointed out in the main plenary address to the 2002 ASEE – Annual Conference at Montreal, is the need for reform of faculty reward systems at the nation’s schools of engineering and technology to better reflect the modern practice of engineering.

As Wulf pointed out in his address:

“I don’t especially want to engage in the teaching vs. research debate. I suspect, like most of you, I believe that teaching and research complement each other. And, by and large, there is a high correlation between good teaching and good research. Good people are good! In my admittedly idiosyncratic career, the number of cases of genuinely good teachers who were not good researchers is very small.

But, in engineering education I think we have an additional problem, and that’s the one I want to emphasize. Recall, my definition of engineering is “design under constraint”. I believe that it’s a synthetic, highly creative activity.

Can you think of any other creative field on campus where the faculty are not expected to practice/perform? Art, music, drama? Even if you won’t buy that engineering is creative in the same way as art or music — performance oriented professions such as medicine and law expect their faculty to practice that profession. Can you imagine a medical school where the faculty was prohibited from practicing medicine?

Yet, not so in engineering.

Faculty are, for the most part, judged by criteria similar to the science faculty — and the practice of engineering is not one of those criteria. The faculty reward system recognizes teaching, research and service to the profession — but not delivering a marketable product or process, or designing and enduring piece of the nation’s infrastructure.

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Of course, *what you measure is what you get*. For the most part our faculty are superb “engineering scientists” — but not necessarily folks that know a lot about the practice of the profession of engineering. At most schools, for example, it’s hard to bring someone onto the faculty who has spent the career in industry, even though such people would be extremely valuable to the students; their resumes simply don’t fit those the reward system values. Sometimes it’s even hard to get recognition for a sabbatical in industry.

Please understand that I am not criticizing the current faulty; I am one of them. And I respect my colleagues greatly. Rather I am criticizing a system that prevents enriching the faculty with a complementary set of experiences and talents. But, to close the loop — of course the current faculty are the folks with the largest say in the engineering curriculum. It should not be a big surprise, that industry leaders have been increasingly vocal about their discontent with the engineering graduates.”9

3. Scholarship Reconsidered

The heightened sense of urgency for reform of faculty reward systems has not happened overnight. Reform has usually been confined to the undergraduate teaching vs. research debate. But reform of professional education extends beyond the limitations of this debate and reaches into the core missions and purposes of modern universities in serving the needs of their constituencies in the 21st century.

3.1 Priorities of the Professoriate

As Ernest L. Boyer pointed out in the landmark report, *Scholarship Reconsidered: Priorities of the Professoriate*: “At the very heart of the current debate — the single concern around which all others pivot — is the issue of faculty time. What’s really being called into question is the reward system and the key issue is this: what activities of the professoriate are most highly prized?”10

Boyer was very clear about his motivation:

“We begin this report on the professoriate by looking at the way the work of the academy has changed throughout the years — moving from teaching, to service, and then research, reflecting shifting priorities both within the academy and beyond. We then note how, following the Second World War, the faculty reward system narrowed at the very time the mission of American higher education was expanding, and we consider how many of the nation’s colleges and universities are caught in the crossfire of these competing goals.

In the current climate, students all too often are the losers. Today, undergraduates are aggressively recruited. In glossy brochures, they’re assured that teaching is important, that a spirit of community pervades the campus, and that general education is the core of the undergraduate experience. But the reality is that, on far too many campuses, teaching is not well rewarded, and faculty who spend too much time counseling and advising students may diminish their prospects for tenure and promotion. Faculty are losing out, too. Research and publication have become the primary means by which most professors achieve academic status, and yet many academics are, in fact, drawn to the profession precisely because of their love for teaching or for service — even for making the world a better place. Yet these professional obligations do not get the recognition they deserve, and what we have, on many campuses, is a climate that restricts creativity rather than sustains it.

Colleges and universities are also weakened by the current confusion over goals …

Ultimately, in the current scheme of things, the nation loses, too. At no time in our history has the need been greater for connecting the work of the academy to the social and environmental challenges
beyond the campus. And yet, the rich diversity and potential of American higher education cannot be fully realized if campus missions are too narrowly defined or if the faculty reward system is inappropriately restricted. It seems clear that while research is crucial, we need a renewed commitment to service, too.

Thus, the most important obligation now confronting the nation’s colleges and universities is to break out of the tired old teaching versus research debate and define, in more creative ways, what it means to be a scholar. It’s time to recognize the full range of faculty talent and the great diversity of functions higher education must perform.

For American higher education to remain vital we urgently need a more creative view of the work of the professoriate …

Finally, we need a climate in which colleges and universities are less imitative, taking pride in their uniqueness. It’s time to end the suffocating practice in which colleges and universities measure themselves far too frequently by external status rather than by values determined by their own distinctive mission … But let’s also candidly acknowledge that the degree to which this push for better education is achieved will be determined, in large measure, by the way scholarship is defined and, ultimately, rewarded.”

3.2 Enlarging the Perspective of Scholarship

Boyer’s report put forth a very plausible justification to enlarge the perspective of scholarship and to unlock the definition of scholarship which is predominantly constrained at too many universities to just scientific research and publication. As Boyer noted, many faculty members are gifted differently and the nation’s universities serve multifaceted missions and purposes.

Whereas Boyer recognized that fundamental scientific research is an important mission of many universities, Boyer also recognized that our understanding of faculty scholarship must be broadened and redefined more flexibly to include other areas of scholarly excellence that cross the full spectrum of what universities stand for and are suppose to do relevant to their new missions and to their new constituencies. Boyer proposed that the work of the professoriate might be thought of as having four separate, yet overlapping, functions. These are:12

- The scholarship of discovery (basic scientific research).
- The scholarship of integration (making connections across disciplines).
- The scholarship of application (application of knowledge in service).
- The scholarship of teaching.

4. Enlarging the Perspectives of Scholarship, Teaching, and Engagement for the Practice of Engineering and Leadership of Creative Technology Development and Innovation

But engineering is neither discovery … nor application — the essence of engineering is creative problem solving and responsible leadership in meeting unsolved human needs.

Less than 5% of the engineering profession is engaged in discovery and scientific research in the United States.13 Thus, as in other professions, the professional educational component and professional faculty reward system for this component should support the technical knowledge, skill-sets, intellectual creativity, professional dimensions, mission and professional maturity factors which are required for advanced practice in the practicing profession.

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4.1 Urgency of Reshaping Faculty Reward Criteria to Advance Professional Education and Practice

The panel agrees with Wulf’s and Boyer’s call for action. The panel recognizes that one of the major issues in reshaping professional engineering education for practice to ensure a strong U.S. engineering workforce for competitiveness is the core issue of reshaping unit faculty reward criteria for those professionally oriented engineering faculty who engage in non-research oriented scholarly activities of a professional nature and who teach in professional engineering programs to advance the practice of engineering. The panel believes that it is futile to talk about initiating and sustaining reform for the advancement of professional engineering education at the undergraduate or at the graduate level if professionally oriented faculty at the nation’s schools of engineering and technology are not provided a complementary unit faculty reward system that recognizes and rewards:

- The distinctive professional scholarship that engineering and technology faculty render through their creative scholarly works to advance engineering practice and leadership of technology development and innovation.

- The time and effort that professionally oriented faculty render in teaching at the basic level of undergraduate education to prepare students for entry into engineering practice; and, at the advanced professional level of engineering education to enable graduate engineers to continuously grow beyond entry-level as technology leaders throughout their professional careers in industry.

- The service to society that high-caliber professionally oriented faculty render: by engaging in real-world problem solving and in meeting real-world needs through their creative engineering practice (yielding meaningful technological advancements for improvement of the quality of life, competitiveness, or the nation’s defense); and by engaging in the advancement of professional education with industry in meeting the educational needs of the practicing profession (ultimately advancing and stimulating U.S. technology innovation and competitiveness by a heightened level of creative, innovative, and leadership capacity within the U.S. engineering workforce).

4.2 Differences Between the Scholarship of Discovery for Scientific Research and the Scholarship of the Practice of Engineering for Leadership of Creative Technology Development and Innovation

To make reform for new faculty reward criteria possible, the panel acknowledges the differences between the scholarship of discovery for research and the scholarship of engineering for creative development. Most of the U.S. engineering workforce is engaged in non-research oriented activities of a professional nature in engineering practice for purposeful needs-driven, conceptual design, invention, development, and innovation of new/improved technology for products, processes, systems, and operations. Yet, faculty reward systems at the nation’s schools of engineering continue to focus predominantly on scholarly work relevant to academic scientific research and publication, the quest for federally funded research, and participation in research-based graduate education for the training of academic researchers with little regard to the professional education of advanced practitioners in the U.S. engineering workforce or to creative faculty scholarly work of a professional nature relevant to the creative development of technology and leadership of technological innovation to meets real-world unsolved needs of people.

The current direction of U.S. engineering education has not been haphazard. During the last half of the last century, universities have placed singular emphasis on academic scientific research as the primary driving force for the advancement of American engineering in industry. And today, U.S. engineering graduate education and faculty reward systems continue to focus predominantly on the linear research-driven paradigm of engineering practice of 1945 [i.e. academic scientific research/discovery of knowledge ⇒ teaching ⇒ application of knowledge]. But, times have changed. Today, it is generally acknowledged in the 21st century that the 1945-linear research-driven paradigm of engineering innovation is in error and is outmoded.
One of America’s greatest inventions has been the development of the purposeful, systematic engineering method and approach to deliberately bring forth new/improved technological innovation to meet unsolved human needs. A breakthrough of new thinking about professional education for the practicing profession and about the scholarly work of professionally oriented faculty has evolved. Engineering has been redefined both as a creative process and as a creative profession. But, for the most part, many of the nation’s schools of engineering and technology have not reflected the new paradigm of systematic engineering practice for purposeful, needs-driven technological innovation at the graduate level.

Singular usage of the 1945-paradigm during the last four decades resulted in a lack of appreciation of what creative engineers do in industrial practice and an underdevelopment of the infrastructure of high-quality professional education for working engineers across the nation. The modern paradigm of creative engineering practice for the purposeful creation, development, and innovation of new/improved technology continues to be largely ignored at too many schools of engineering and technology across the nation or not recognized at the graduate level of professional engineering education. Most engineering graduate faculty have been trained for scientific discovery and are being rewarded predominantly for their scientific research achievements, for their publications in research journals, and for their successful quest of federal research funding per the 1945-linear research-driven model of engineering, which has resulted in a long-term disconnect between U.S. engineering education and practice.

This long-term disconnect has contributed to the long-term stagnation of U.S. innovative capacity and to the gradual decline of the nation’s technology posture for world-class competitiveness. As a result, the U.S. engineering workforce has been underdeveloped as a national resource for systematic technological innovation for competitiveness during the last four decades and the nation’s professionally oriented faculty at the nation’s schools of engineering and technology have been undervalued, under rewarded, and underdeveloped as well. This situation will continue, in all probability, unless corrective change is purposefully planned and put into action. Although the advancement of fundamental scientific research, the training of future academic researchers, and the development of research-oriented faculty is crucial to the nation’s scientific strength, so is the advancement of creative engineering practice, the further professional education of the U.S. engineering workforce for leadership of creative technology development and innovation in industry, and the development of professionally oriented faculty at the nation’s school’s of engineering and technology crucial to the nation’s technological strength.

4.3 Correcting the Disconnect Between Professional Engineering Education and Practice

Although popular misconceptions about the roles of scientific research for discovery and the roles of creative engineering practice for technology development still persist within the nation, the National Academy of Engineering (NAE) has initiated a national effort to begin to correct these popular misconceptions through its landmark report: Technically Speaking. As a result of the NAE report, engineering and technology have been redefined for the 21st century. Engineering has its own distinctive mission, and the paradigm of engineering practice for the conceptual design, development, and innovation of new/improved technology has changed substantially since 1945.

As Wulf remind us, engineering should be viewed today as “design under constraints” to meet the real-world needs of society. Engineers set the vision for new technology and they must conceptually design, invent, develop, and innovate new technology continuously as a purposeful systematic practice to meet real-world needs in the form of new/improved products, processes, systems, and operations. The engineering method that is used today is a deliberate and systematic practice which is needs-driven and market-focused for the purposeful conceptual design, deliberate invention, development, and innovation of technology in the form of new/improved products, processes, systems, and operations. No longer is engineering considered merely “applied science” or the transfer of basic scientific research discoveries and findings from the research laboratory bench into commercialization … and it never was that. Nor is
engineering considered any longer as a sequential follow-on activity to scientific research wherein popular misconceptions previously perceived the primary purpose of scientific research was to discover knowledge and the primary purpose of engineering was to apply that knowledge.

Advancements of U.S. competitiveness are achieved primarily through the creative intellectual work and engagement of working engineers in industry who engage in creative engineering practice and the conceptual engineering thought process for new technology development and innovation. In this process, most engineers work as creative professionals and they frequently drive the need for new science (directed applied research) at the nation’s research universities and government laboratories. Contrary to popular belief, the modern practice of engineering does not begin with fundamental scientific research as the driving force. Rather, effective engineering innovations begin with strong engineering leadership for improvement with the creative recognition of meaningful unsolved needs as the driving force, which then must be solved creatively and responsibly through application of the purposeful systematic engineering method and approach which is integrative with directed applied research when the need for research arises during the directed creative technology development project.

4.4 The Changing Concept of Scholarship for Changing Times

From these perspectives, the panel believes that it is time to redefine scholarship in a broader context — especially that of professional scholarship, teaching, and engagement for the advancement of engineering practice to meet real-world human needs, both domestically and globally. The panel is perceiving the notion that the unit criteria of scholarship for the pursuit of high-caliber engineering practice may be quite different from the unit criteria of scholarship for the pursuit of high-caliber scientific research because the methods, purposes, skill-sets, and contexts of these two different pursuits are quite different. Although there are similarities between science and engineering, the panel acknowledges that the purposeful advancement of science and the purposeful advancement of engineering practice for responsible leadership of creative technology development and innovation are two very different pursuits. Accordingly, the unit faculty reward criteria for these two different pursuits must be quite different.

But little change for reform of faculty reward systems has occurred since Boyer’s report was written over fourteen years ago. As the Kellogg Commission has pointed out, universities must undergo substantial changes to better serve their new missions and multiple stakeholders in the 21st century. However, the panel recognizes that any attempt to make a breakthrough from conventional wisdom to a new concept of scholarship requires us to understand that we may encounter some resistance along the journey. The panel believes that the use of Barwise and Perry’s theory of meaning is extremely important in initiating and sustaining educational innovation at the graduate level. As Barwise and Perry have noted:

“Different organisms can rip the same reality apart in different ways, ways that are appropriate to their own needs, their own perceptual abilities and their own capacities for action. This interdependence between the structure its environment displays to an organism and the structure of the organism with respect to its environment is extremely important. For while reality is there, independent of the organism’s individuative activity, the structure it displays to an organism reflects properties of the organism itself.”

4.5 What is Scholarship?

The panel believes that Barwise and Perry’s theory of meaning helps: (1) to understand that the meaning of scholarship will probably be perceived differently by different types of scholars within the multicultural university community, and; (2) to understand that different organizational cultures may strongly influence the different ways people “rip reality apart” from their own perspectives, situations, attitudes, and capacity for action. Thus, scholarship may mean different things to different people in the 21st century...
university. The term scholarship may have one predominant meaning for the already tenured academic scientific researcher, who is currently working under the existing faculty reward system, yet the term scholarship may embrace another meaning for the creative working professional and professionally-oriented faculty member. Because the meaning of terms is extremely important in enlarging the concept of scholarship, the panel defines: a scholar as one who is pursuing advanced study and is engaged in creative intellectual work; and scholarship as the qualities, skill-sets, or attainments of a scholar relevant to advancing new creative outcomes or “ideas and concepts” to advance that field of study or profession.

From this perspective, the panel proposes two questions for investigation that may help to differentiate the scholarly work of a research scientist from that of the scholarly work of an engineer.

1) What are the qualities, skill-sets, and attainments of scholars who pursue scientific research activities for the advancement of science?

2) What are the qualities, skill-sets, and attainments of scholars who pursue professional activities for the advancement of engineering practice, technology development, and innovative leadership in meeting unsolved human needs?

4.6 Constructing a New Template for Professional Scholarship, Teaching, and Engagement to Advance the Practice of Engineering and Leadership of Technology Development and Innovation

The need for diversity of scholarship is at the center of reform to create new unit faculty reward criteria for professionally oriented faculty in professional engineering programs. From Boyer’s perspective: “The richness of faculty talent should be celebrated, not restricted … Only as the distinctiveness of each professor is affirmed will the potential of scholarship be fully realized.” The panel finds that Boyer’s perspective of the distinctiveness and diversity of faculty talent is refreshing.

Although Boyer’s report was a landmark for scholarship reform, the panel has recognized that Boyer nevertheless neglected the distinctive elements of “professional scholarship” and the distinctive elements of “creative engagement for service” that are the unique properties of what the creative professions do — especially that of creative engineering practice for service to society through original creative design, technology development, improvement, and the responsible leadership of purposeful technological innovation to advance the quality of life. Because creative service to society has been, and continues to be, the primary mission of the engineering profession, the panel believes that the engineering profession itself, perhaps more than any other profession, can benefit from a redefinition of creative professional scholarship and creative engagement.

However, making reform of faculty reward systems a reality requires us to “break out of the box” of conventional wisdom about engineering graduate education. The panel has become aware through our collective experiences, successes, and mistakes that Barwise and Perry’s theory may be correct … i.e. the human mind in its acceptance of new thinking is not independent of the strong organizational influences which embrace conventional thought and existing paradigms. Thus, the panel recognizes that the process of making reform of faculty reward systems a reality on campuses of engineering and technology across the nation will not be easy and may require further development at least through the initial prototype stages of framework development which must be contrasted with similar situations so that the new “idea or concept” can be seen more clearly.

The struggle for developing and sustaining high-quality professional education at universities has been difficult at best. The arts and sciences have had great difficulty in realizing that universities serve multifaceted missions other than their own — one mission of which is the professional education of practitioners for service to society. And many schools of engineering are having a difficult time sorting
out priorities between science and technology. The panel has learned through its investigations, readings, and discussions that many situations are common across the nation:

- Faculties frequently come to schools of engineering and technology with one set of expectations to teach and to do creative professional scholarship in engineering and then are asked to do scientific research.
- Frequently schools of engineering and technology recruit new faculty members as if they were the physics department or chemistry department.
- Seldom do these schools build on their distinctiveness or consciously try to seek out faculty members who want to teach in the realm of creative engineering practice, technology leadership and innovation, or to do creative engineering work relevant to the needs of industry or society primarily because of the existing faculty reward system.
- Most campuses across the nation still equate scholarship with scientific research, attainment of federal funding, and research journal publications. As a consequence, schools of engineering and technology have largely become imitative of schools of science during the last four decades.

What is urgently needed today in engineering and technology education is a new framework for scholarship that is not imitative of scientific research. And what we urgently need are new models for faculty reward criteria for the nation’s schools of engineering and technology that complement models for research and that give distinctiveness to the mission of engineering professional education both at the basic level and at the advanced level for creative engineering practice, creative scholarship, and leadership of technology development and innovation in the mission and spirit of the practicing profession. The panel acknowledges that implementing this much needed reform and creating new faculty reward systems as a complement to research will not be easy.

But reform of faculty reward systems can be made, is attainable, and must occur for the nation to regain its strength in professional engineering education to improve its posture for technological competitiveness. The panel recognizes the reality of the situation and should not be surprised at the degree of resistance that may occur at universities when we broaden the notion of scholarship to include professional scholarship, teaching, and engagement for creative engineering practice and the leadership of innovative technology development.

However, the probability for successful reform is high. The driving force for reform of professional engineering education — to ensure a strong U.S. engineering workforce for competitiveness and to ensure a strong educational infrastructure that supports the workforce — rests with the collective strengths of the practicing profession itself, the wisdom of the national academy, and the combined strengths of industry and government who as no other stakeholders recognize the need for rebuilding the nation’s capacity for technological innovation in industry and the impact that the universities can make to society in implementing this much needed reform.

As America competes in the innovation-based, global economy, it must build upon the strengths of its system of higher education and the competitive advantage of the American industry. But the nation must take deliberate action to improve the infrastructure of U.S. engineering education for innovation whereby professional education should no longer take second place at the nation’s schools of engineering and technology. As the ASEE 2004 January Prism noted: America’s ability to create and innovate will keep the nation a frontrunner in the global arena for technology.20

Conrad, Haworth, and Millar noted in their landmark report (and follow-on findings) for the Council of Graduate Schools that a primary attribute for developing and sustaining innovative, high-quality
professional graduate programs is the effective use of professionally oriented core faculty, who have worked full-time in their professional careers in non-university work settings. But innovative, high-quality professional graduate programs in engineering cannot reach their long-term potential for sustainability unless the core professional faculty are further developed and rewarded.

Tenure and promotion criteria must be commensurate with the skill-sets that support the mission of the professional graduate programs. In a similar manner, the panel concludes that the term engineering practice itself must be redefined as it means much more than the mere application of knowledge as conventional wisdom and the 1945 linear research-driven model of engineering practice and higher education portrayed.

As Scheffler has pointed out:

“The ambiguity of practice is thus of paramount importance in the education of skill. It is, for example, of critical importance in professional education, for the doctor, the [engineer], the lawyer, and the teacher are not simply persons who have acquired technical facilities which can be run off automatically; they need competences which require the continual exercise of strategic judgment concerning individual cases which they have never confronted before and for which there are no exhaustive rules dictating decisions to be made. Practice in professional education is thus misconceived if assimilated to the model of drill or to the repeated study of standard cases. There needs to be room for training opportunities which will provide for the genuine exercise of students’ judgment, as well as for critical reflection on the outcomes and strategic principles of such judgement.”

From this perspective, the panel proposes that the core professional faculty who teach advanced engineering practitioners in professional graduate programs for this type of innovative engineering practice for world-class competence will have knowledge, attainments, and experiences that are quite different from those required for world-class competence for scientific research. Thus, the panel suggests that the framework for creating a new template that better reflects a complementary faculty reward system for core professionally oriented faculty in engineering and technology should include three predominant factors. These are:

- **Professional Scholarship.** (Scholarship of a professional and creative nature oriented toward creative engineering practice and technology leadership that creates new ideas, concepts, original designs, creative solutions performed through creative engineering problem solving, original creative technology development and the engineering leadership thereof to advance engineering practice and the leadership of technology development and innovation).

- **Teaching.** (Teaching of a professionally oriented nature at both the basic level of engineering education (undergraduate) for entry into engineering practice and at the advanced professional level of engineering education (graduate) that enables positive growth of experienced practitioners beyond entry-level in creative engineering practice and technology leadership.

- **Engagement** (Creative service to regional, state, and national interests responsive to meaningful, real-world problems and needs of society and to the practicing profession).

The panel suggests that the differences between the functions of science and engineering (Appendix A) and the professional engineering skill-sets, technical knowledge, attainments, and practical experience required for responsible engineering leadership of technology development and innovation in engineering practice (Appendix B) may serve as conceptual guidelines in creating a new template for unit criteria for professionally oriented faculty.
5. Drawing the Right Conclusions

The panel has pointed out that the pursuit of fundamental scientific research for discovery and the pursuit of creative engineering practice for leadership of technology development and continuous innovation are quite different from that previously portrayed by the 1945-basic research-driven model of engineering that has also driven the faculty reward system. A new paradigm has evolved for the modern practice of engineering in the 21st century that has caused the linear research-driven paradigm of engineering practice of 1945 to become outdated. The creative professional engineering thought process, the creative professional scholarship process, and the supporting educational culture that is required to develop intrinsic human potential through the nine progressive levels of leadership responsibility and professional maturity for creative and innovative engineering practice to conceptualize and lead the continuous creative development of new/improved technology in industry and mission-oriented government agencies is quite different from that required for academic scientific research investigations.

The new paradigm for creative engineering practice and technology leadership requires a different type of unit faculty reward system and an oversight mechanism for those professionally oriented faculty who are pursuing excellence and a heightened level of professional maturity in creative engineering practice, leadership of technology development, and teaching careers, and who are advancing the practicing profession of engineering through their creative practice and professional scholarly work. This paper lays the conceptual foundation for initiating this reform. However, the panel members are not proposing to change unit tenure promotion criteria for research-based graduate education to reflect that of engineering practice. Our intent is to develop a complementary set of unit tenure promotion criteria and an oversight mechanism that supports and rewards creative professional scholarship, teaching, and engagement in engineering practice for the advancement of technology and its leadership in the mission and spirit of the profession. These new unit criteria should not be viewed as weakening the existing criteria that support the research mission of universities. Rather these new unit criteria are different; they should be viewed as complementary criteria to scientific research; and, they should strengthen the professional education mission of universities for excellence in creative engineering and technology activities.

References

11. Ibid.
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**Biography**

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Appendix A

Functions of Creative Engineering Practice and Scientific Research

Creative Engineering Practice

Creative Technology Development

… The role of needs-driven systematic technological development in industry and government is the purposeful invention 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.” 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).”

Scientific Research

Basic and Directed (Applied) Research

… The role of basic 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 directed (applied) research in industry and government is the 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 solution of specific problems 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 (applied) research group is needed for immediate problems.

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Appendix B

Professional Engineering Skill-_sets, Technical Knowledge, and Practical Experience Required for Responsible Engineering Leadership of Technology Development and Innovation in Industry
### Appendix B -1

A Comparison Between Career Paths that Support Academic Research at Universities and those that Support Engineering Practice and Leadership Of Technology Development in Industry / 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></td>
</tr>
<tr>
<td>Engineer IX (GS-18, 17,16)</td>
<td></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>Administrative Academic Levels</td>
</tr>
<tr>
<td>Engineer VIII (GS-15)</td>
<td></td>
</tr>
<tr>
<td>Director of Engineering</td>
<td>Department Head</td>
</tr>
<tr>
<td>Engineer VII (GS-14)</td>
<td></td>
</tr>
<tr>
<td>Department/Division Manager</td>
<td>Distinguished Professor</td>
</tr>
<tr>
<td>Engineer VI (GS-13)</td>
<td></td>
</tr>
<tr>
<td>Technical Area Manager</td>
<td>Professor</td>
</tr>
<tr>
<td><strong>Senior Engineer/Project Management Levels</strong></td>
<td>Senior Research Specialist Levels</td>
</tr>
<tr>
<td>Engineer V (GS-12)</td>
<td></td>
</tr>
<tr>
<td>Senior/Principal Engineer/Project Leader/Group Leader</td>
<td>Associate Professor</td>
</tr>
<tr>
<td>Engineer IV (GS-11)</td>
<td></td>
</tr>
<tr>
<td>Project Engineer/Process Engineer</td>
<td>Assistant Professor (PhD)</td>
</tr>
<tr>
<td>Engineer III (GS-9)</td>
<td></td>
</tr>
<tr>
<td>Design/Development Engineer</td>
<td>Post-Doctorate in Research</td>
</tr>
<tr>
<td><strong>Entry Level in Engineering Practice</strong></td>
<td>Entry Level in Academic Research</td>
</tr>
<tr>
<td>Engineer II/I (GS-7, 5)</td>
<td></td>
</tr>
<tr>
<td>Entry Level Engineer/Engineer-in-Training</td>
<td>Graduate Research Assistant</td>
</tr>
</tbody>
</table>

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Appendix B-2
Characteristics, Growth Levels, and Professional Leadership Responsibilities 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.

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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, Ass't 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 nonroutine 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, Ass't 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)
## Stages of Growth and Professional Responsible Charge for Engineering Leadership of Technology Development and Innovation in Industry / Government Service

<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>

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Appendix B-4

Core Qualifications, Professional Skill-Sets, Technical Knowledge, and Practical Experience Required in Engineering Practice for Leadership of Technology Development and Innovation in Industry and Government Service

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-Sets, 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.

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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 – 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) A broad education necessary to understand the impact of engineering solutions in a global and societal context. A recognition of the need for, and an ability to engage in lifelong learning.

i) A knowledge of contemporary issues.

j) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.