# A New Program in Leadership Engineering

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***Abstract*— The University of Texas at El Paso (UTEP) is planning to pioneer and establish a new undergraduate program in Leadership Engineering. The overarching program goal is graduation of a new pedigree of qualified engineers with the "soft skills", business acumen and strategic foresight, in addition to engineering prowess, to meet the needs of industry in the 21st century.**

**Following the recommendation from James Duderstadt's "Engineering for a Changing World" [1], we propose a new paradigm for the education of the engineering leaders of the 21st century. The Duderstadt model mirrors the medical school training model that is credited with propelling advancement in medical practice during the last century, where the BS degree includes a broad-based curriculum of engineering design, project management, technology, ingenuity and innovation, along with business, communication, ethics, and social sciences. This foundation is then followed by post-graduate study, via a professional Master's degree program, in a specific discipline or concentration. The Leadership Engineering degree program is a first important, and viable, step towards that new paradigm.**

**A large fraction of the graduates of the Leadership Engineering program are anticipated to pursue professional graduate degrees in a variety of engineering fields. Through a curriculum that provides a framework for building successful businesses, students graduating from the program may also move into the booming technology services sector or choose to start their own innovative companies. Finally, graduates of the Leadership Engineering program will be prepared to serve as leadership engineering educators in the K-12 sector, or for further graduate preparation in the expanding field of engineering education.**

***Keywords – engineering education, soft skills, curriculum, professional graduate program, service industry, entrepreneurship, K-12 education.***

## I. Introduction

The University of Texas at El Paso (UTEP) is planning to pioneer and establish a new undergraduate program in Leadership Engineering. The overarching program goal is graduation of a new pedigree of qualified engineers with the "soft skills", business acumen and strategic foresight, in addition to engineering prowess, to meet the needs of industry in the 21st century. The genesis of this program is a result of a combination of increased global competition, piecemeal improvements in engineering education over the last forty years, and emerging markets for engineers with a very broad skill set. The purpose of this paper is to outline the market forces that necessitate a sweeping change to the way we educate engineers, describe the fundamental elements of a program that we believe is an appropriate response to these market drivers, and propose next steps in this evolution of the engineering education paradigm.

These converging competitive and market forces require something beyond piecemeal renovation of engineering education within the current paradigm. Indeed they require a sweeping change in engineering education resulting in a new model for the future. And since the current paradigm is entrenched in engineering schools borne out of the land-grant/flagship institution of the 19th and 20th centuries, perhaps the appropriate environment for the implementation of the new paradigm is the University of the 21st Century – a regional, urban institution with demographics that more closely match the future demographics of the U.S.

There is also a critical need to attract top talent to the field of engineering. Over the last two decades or more, engineering enrollments have remained relatively stagnant, female enrollment has been steady at a paltry 15-20% (during which time enrollment of women in medical schools has increased to over 50%), and we have witnessed a longstanding underrepresentation of blacks and Hispanics coupled with a trend towards a minority majority population in the U.S. This mounting evidence points to the need to attract the leaders of tomorrow to the engineering profession today.

## II. A New Engineering Education Paradigm

### *A. Call for Change*

The window for sweeping change in engineering education was opened in 1996 when the ABET Board of Directors adopted new criteria for accreditation of undergraduate engineering programs, which have become known as *Engineering Criteria 2000*. These new criteria shifted the focus from content (what is taught) to outcomes (what is learned), and required a rigorous process of measurement, assessment, and program improvement. The expected learning outcomes now include project and professional skills, such as communication, team management, ethics, and understanding of societal and global issues, beyond the usual technical competencies. These new criteria had a profound effect on the design and implementation of programs in the U.S. over the course of the decade preceding and following introduction of the new criteria. A 2006 study [2] of the impact of these criteria changes on the preparation of engineering graduates for professional practice concluded that indeed engineering graduates in 2004 were better prepared than their counterparts in 1994 in terms of project and professional skills, and yet were still equally prepared in their technical skills. Most of the significant increases in preparedness were measured through self-reporting by the students. When employers were surveyed [2], their responses were much more mixed (some positive, some negative changes) and the increase in skills was perceived to be much more modest than the student's self reporting.

A second opportunity for sweeping change in engineering education occurred when ABET announced in 2008 that it will now allow institutions to seek accreditation at both the BS and MS level for the same discipline. This decision most certainly now opens the door for the development of accredited, professional engineering programs at the MS level.

According to an ABET viewpoint published in 2007 [3] during the open discussion phase of this determination, the consideration of this change was at least in part based on the recommendations made in the National Academy of Engineering's (NAE) report *The Engineer of 2020* [4], including "the adoption of the master's-level degree as the first professional degree in engineering." This NAE report also calls for "engineers who are broadly educated, who see themselves as global citizens, who can be leaders in business and public service, and who are ethically grounded." More than any other report in recent times, *The Engineer of 2020* sparked considerable debate and discussion: not on whether engineering education should continue to change, but on how, how much, and how soon this change should happen.

Following the 2004 NAE report, the National Science Board (NSB) convened two seminal workshops [5] in 2005 and 2006, to move "forward the national conversation on engineering issues by calling attention to how engineering education must change in light of changing workforce demographics and needs." The workshops focused on three "challenges" for engineering education: 1) requirements of engineers to compete in the global marketplace through competitive differentiation, 2) society's perception of the profession of engineering, and 3) retention of engineering students. The "keystone" recommendation encouraged the expansion and reinvigoration of the current NSF programs that fund innovation in engineering education, with the hope that they will eventually produce "systematic change in perceptions and retention of engineers" that, to date, has not yet occurred, in their opinion [5]. In 2007, the Carnegie Foundation for the Advancement of Teaching issued a study to examine the current state of preparation for the engineering profession [6]. The "imperative for teaching for *professional practice* (italics added)" emerged as a primary recommendation from this study. The authors also suggest a change in engineering curriculum design from the rather linear model (theory followed by applications) currently used to a more integrated, iterative model that can best be described as a spiral, "with all components revisited at increasing levels of sophistication and interconnection."

Changing the perception of the engineering profession and, with that given perception, promoting the ability to attract the best and brightest into this field, become a key driver in the call for change. In a 2007 IEEE opinion piece [7], George McClure provides a prescription for those engineers who are under threat of being commoditized by the decreased demand in the US for engineers due to technology-based increase in productivity and lower cost off-shore engineering services: add right brain (integration, contextualization, synthesis) thinking to the left brain (sequential, analytical, rote) repertoire of the typical engineer. This matter of engineer actualization is currently being tackled by the NAE [8]. They are promoting a "change in conversation" in framing engineers and their identity from "must do well in math in science" to "make a world of difference" and "turn ideas into reality." In making this recommendation, the NAE specifically compared the engineering profession with the medical profession. Physicians are professionals who "cure disease and relieve human suffering," not people that "must do well in organic chemistry."

A common element in all of these reports is the desire and need for major change in engineering education, however none prescribe specifically how these changes can be sufficiently addressed in a four-year undergraduate curriculum. In the ABET study [2] reported earlier, it was acknowledged that most of the non-technical outcomes were a result of learning through extra-curricular experiences. Certainly a prominent deterrent to the needed change described in all of these reports is the combination of shrinking credit requirements, from the typical 140-150 semester credit hours required in the 1970's to the 120-128 hours mandated now by many states, along with the increasing technical expertise (including the current bio-nano-info triumvirate) expected of our graduates. This leaves very little room *within* the curriculum to include learning of the professional skill set. Thus, a significant part of the discussion and debate has centered on the need to transform the current undergraduate engineering degree to a more broad-based "liberal" pre-engineering degree program, followed by professional training in the discipline at the graduate level. King [9] and Duderstadt [1] each promote a transition to a medical school model as the appropriate solution to increasing the stature of the profession, attracting top talent into the profession, and competitive differentiation within global markets. Unfortunately, like all of the previous reports mentioned here, neither of these proponents of the *Engineer of 2020* education paradigm provides specific guidance to engineering educators on what the transition model, that may be used to progress from our current mode to this new paradigm, should look like. Both acknowledge that the transition will be quite difficult, and is complicated by the diverse set of constituents (education, industry, accreditation, licensing, and professional societies) that will all need to eventually agree on the proper solution.

### *B. Market Requirements*

One of the difficulties in the transition into a pre-professional engineering BS level degree program is placement of students that do not progress on to the professional graduate training stage. As Duderstadt [1] notes, there is typically a "mismatch between the broader skills that industry leaders claim they need and the very narrow criteria imposed by their campus recruiters," driven in part by the need to "deliver engineering graduates capable of immediate impact" via their technical skills. Thus there is concern that graduates of a broad-based, liberal BS program, who do not progress on to the professional graduate programs, will not possess specific technical skills required for a particular industry sector. However, in the past few years, potential markets have opened up that we believe require the skills that a broad-based, liberal BS engineering program would produce.

When IBM Corporation began to heavily invest into the digital computer market, it became very clear that they needed a new brand of professional that was not being produced in the current science and engineering programs. Thus the discipline of computer science was born and became a distinct discipline in the late 1950s and early 1960s. Now fifty some years later, IBM has moved a significant amount of its resources away from the development of products and towards the provision of services. The skill-set needs of this service-oriented industry are a mix of technology, business practices, and organizational management. Once again, a situation exists where a program that produces engineers or scientists with that skill set does not currently exist. So now IBM is promoting another new discipline – Service Science, Management, and Engineering (SSME). According to their web site [10], SSME is defined as "a growing multi-disciplinary research and academic effort that integrates aspects of established fields like computer science, operations research, engineering, management sciences, business strategy, social and cognitive sciences, and legal sciences." The purpose of this discipline is to "find ways to increase productivity and innovation in services-related industries and tasks by applying scientific means and methods [11]." The engineer working in this field must attain a very broad-based skill set, including engineering, business, and social sciences – a list strikingly similar to those expected from the broad-based, liberal engineering programs previously mentioned. According to IBM, they are not alone in this need. The service sector has grown to represent 80% of the US economy – including other giants such as AT&T, Accenture, Hewlett-Packard, and Electronic Data Systems (EDS), and it accounts for over 50% of the economies of Brazil, Germany, Japan, Russia, and the UK [11]. China is not far behind at 35%, but, as you might imagine, is the fastest growing of the entire group.

Another potential market for a broad-based, liberal engineering program is in the area of education. Many of the reports listed earlier [4,5,8] point to the need for optimal mathematics, science, and engineering education at the K-12 level, to draw more talented students into the field, and ensure that they are adequately prepared. There is also a need to grow the diversity within engineering, mathematics, science and technology (STEM) fields, growing the presence of minorities and most especially women. Many states are now considering, or have approved, the addition of engineering knowledge to the science and mathematics requirements for grades 9-12. For example, the Texas Essential Knowledge and Skills (TEKS) [12], is currently changing to include engineering fundamentals and design options, and requires a skill set in career and technical education that includes courses in Information Technology (IT), Manufacturing, Transportation and Logistics, and STEM, starting in Fall 2010. The Texas school systems are currently (and somewhat frantically) seeking qualified engineering-educated personnel to teach these courses. To fill this need, the Texas UTeach Engineering Program [13] began offering summer certificate and MS degree programs to train current teachers in engineering instruction, and introducing a teacher certification program for undergraduate engineering majors. The need for qualified K-12 engineering educators will continue to increase nationwide, and an appropriate BS degree program is needed for a long term solution.

A second part of the engineering education market is the growing number of graduate programs in engineering education which produce educators that are change agents for the field of engineering education (see for example, the program at Virginia Tech [14]). These leaders undertake research in fields that include engineering epistemologies, learning mechanisms, systems, diversity and inclusiveness, and assessment. These fields have been identified as contemporary major engineering education research fields that are part of the expanding field of engineering education research [15]. There is a growing list of peer-reviewed journals for publication in these fields, and the challenge of achieving a transformation in engineering education is being discussed. While these graduate programs can and do recruit students from all engineering disciplines, we believe an optimal foundation for an engineering education graduate degree program is a broad-based, liberal engineering degree program.

### C. *Engineering Leadership Programs*

A very common objective of engineering programs in the US is to produce future engineering leaders. However, very few programs actually have curricular content that specifically addresses the skill set of leaders. Many current engineering leaders developed their skills through post-graduate leadership training (most typically in business schools via the MBA) or in industry settings (see for example the Lockheed Martin Engineering Leadership Program [16]). The Bernard M. Gordon MIT Leadership Program has developed a white paper [17] summarizing a few of the current undergraduate programs in engineering leadership worldwide, and describing some best practices based on the success of those programs. They define leadership programs as those that develop all or a portion of the following general skill set:

- Initiative and decision-making
- Systems thinking
- Networking and relationship building
- Creating a compelling vision
- Teambuilding and management to completion
- Problem solving and critical inquiry.

All of the programs described in this white paper are either extracurricular in nature (typically project-based or mentoring) or designed as an adjunct (from a single course to a full minor) to an engineering baccalaureate program in a traditional discipline.

The MIT white paper also noted that there are many similar entrepreneurship education programs that include a "significant focus on leadership [17].” A very strong argument can be made that the skill set described above for engineering leaders is as appropriate for entrepreneurs as it is for corporate managers, VP’s, and CEO’s. As such we argue the connectedness and interrelationship between engineering and business, being entrepreneurship, can be recognized and appreciated as important within many roles in contemporary professional engineering endeavor. The resounding call for change, coupled with market requirements and emphasis on leadership in engineering education programs, leads us to propose a new program.

## III. The Proposed Program

We have chosen the term Leadership Engineering to describe our proposed BS-level broad-based, liberal engineering program. A primary objective of this program will certainly be to produce the engineering leaders of tomorrow. However, our proposed design is somewhat a reversal of the usual style of developing leaders from engineers. The premise for typical Engineering Leadership programs is that you start with an engineer and then make a leader out of him or her. Thus Leadership training is the primary focus, with Engineering as the qualifier for the type of leaders being trained. The premise of our Leadership Engineering program is that the profession will attract future leaders (as is the case of many other professions that require post-graduate professional training, such as medicine and law), and the program is designed to produce engineers out of those future leaders. Thus it is a broad-based, liberal engineering program for future leaders in the public and private sectors.

### *A. The Model Summary*

In Duderstadt’s sweeping position statement on the future of engineering practice, research, and education [1], he renews a call for the “renaissance engineer, engineering graduates capable of a broad range of activities from technology to management to public service.” One of his primary arguments for this call is in the name of global competitiveness. In his view, we simply cannot compete with the likes of China and India in the long run in terms of the quantity of engineers. We must compete in the global market by adding value to U.S.-produced engineers, raising the quality of technology-based innovation in the U.S. He also echo’s the advice of Wayne Clough, primary architect of the *Engineer of 2020* [4], that “we should also emphasize leadership as the basis for engineering education.”

Duderstadt’s recommendations call for:

- Establishment of “graduate professional schools of engineering that would offer practice-based degrees at the post-baccalaureate level as the entry degree into the engineering profession”
- Restructuring of “undergraduate engineering programs as a liberal arts discipline.”

The essential skill sets recommended by Duderstadt for learning outcomes in a liberal undergraduate engineering curriculum are synthesis, design, creativity, innovation, and entrepreneurship. Within these skill sets are such particulars as problem formulation, management of complexity and uncertainty, teamwork, multicultural understanding, systems thinking, decision making and influencing, and knowledge integration. In his model, the engineering science and practitioner education would be mostly provided at the graduate level, and it is the graduate program for which the institution would then seek accreditation. In this case the professional graduate programs would admit students from a variety of disciplines, including the liberal engineering program.

As we mentioned earlier, our attempt here is to design a program that will help us, and other programs like ours, to transition to this encompassing model over a generation or two. Therefore, in our first iteration of this model we expect to seek accreditation of the Leadership Engineering program under the current criteria for Engineering (general) programs. We also want to ensure that graduates of the program who do not move on to professional graduate programs have a market for their skill set as well. Therefore, in addition to the elements recommended by Duderstadt, we will also have elements of the program that specifically address engineering science and practice, as well as discipline-based engineering courses that will adequately prepare the student for a graduate professional program in that same discipline.

We hope that Leadership Engineering will provide a quality engineering education pathway that advances leadership and is followed by various professional practice degrees. Note that our proposed model melds alongside current traditional engineering program offerings. At the same time it clearly points the way toward achievement of new engineering education paradigms.

### *B. Programmatic Components*

In this section we describe what would be the basic programmatic components of a broad-based, liberal undergraduate engineering program. At this stage in the program development, we are assuming that the program learning outcomes will include the ABET a-k outcomes, along with additional outcomes recommended by Duderstadt and listed above. For the purposes of this paper, we will merely list and describe the programmatic components that will contribute to these general outcomes.

The 120-semester credit hour proposed program might well be divided into four components, as listed in Table I. Typical engineering program design would call for a linear, progressive sequence of courses in the general order as shown in the table, where a student starts with a solid foundation of general education and the science and math components, builds on that foundation the framework for engineering via the engineering topics, and then “tops” off that knowledge base with track components in management, education, or entrepreneurship. This linear model almost by its design confines teaching strategies to being deductive in nature. Sheppard [6] argues for a spiral model of component progression, where these four components (in our case) would be interwoven in a spiraling network fashion, “with all components revisited at increasing levels of sophistication and interconnection,” and where “learning in one area supports learning in another” in a continuous spiral towards the degree completion. She also recommends the development of a "professional spine" to this spiral to allow linkages between theory and practice throughout the curriculum.

Our program, as depicted in Fig. 1, will best be described as a helical staircase. The central support column of the staircase represents the design practicum which will serve as the "professional spine" of our program, and where linkages will be made between theory developed in the stair steps and professional practice through design. We suggest enhancing engineering design education by promoting and facilitating the use of problem-based learning (PBL) [18], thereby improving students' key transferable skills and their grasp of the subject content. What makes PBL different from conventional teaching is that it starts with problems related to real world practice. This makes it different from conventional teaching where content is first taught in lectures and then applied by solving problems in tutorials and assignments. PBL is designed to help you become an independent learner but it does not do this by using a "sink-or-swim" approach.

TABLE I. PROGRAMMATIC COMPONENTS

| Component Title | Credits |
|---|---|
| General Education | 27 |
| Science and Mathematics | 30 |
| Engineering Topics | 45 |
| Management Track<br>or<br>Education Track<br>or<br>Entrepreneurship Track | 18 |
| **Total Program** | **120** |

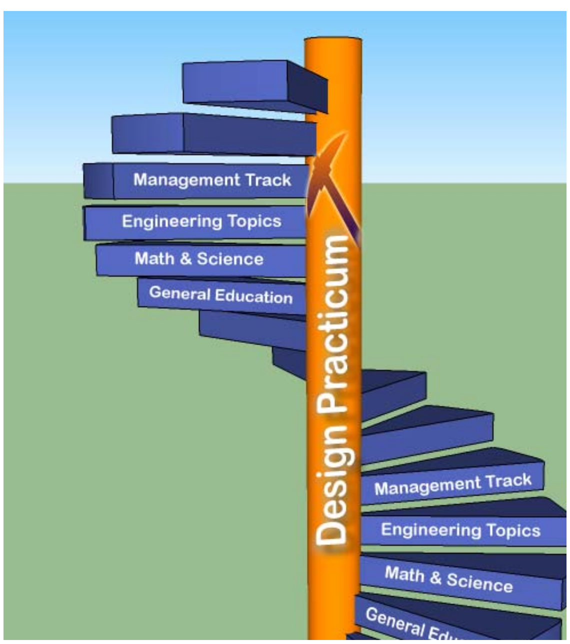


Figure 1. Helical Staircase Curricular Model.

Instead, it provides students with plenty of support as they develop the skills needed for learning in a PBL team [18]. Each of the steps represents courses (or topics within courses) within each of the four program components. The stair "topics" will continuously rotate through each of the four components (discussed hereunder) as the student traverses through the curriculum, eventually arriving at the goal of Leadership Engineering degree completion.

Skills taught within and radiating from the spine of the connected staircase include an interwoven tapestry of communication in all its various forms, creativity, interpersonal and team working skills, mathematical and numerical ability, use of technologies, self learning skills, problem solving and business skills, project management and literacy skills.

The curriculum will also be designed thematically around a variety of modes of inquiry, and experiential learning opportunities will be integrated throughout the curriculum. The modes of inquiry will go beyond the usual quantitative, deductive, and inductive reasoning typically utilized in engineering instruction, and thus the instruction will include aesthetic and interpretative approaches as well.

The distinguishing objective of the program is concurrent development of character, professionalism and quality. The use of multiple modes of inquiry will instill in graduates a strong sense of values, and the ability to think critically and make connections contextually across disciplines.

The program will provide in-depth and concurrent learning of core principles in leadership and engineering. The resultant graduates will have distinguishing characteristics and background reflective of this concurrency. Our budding engineering leaders will grow through a vigorous program of coursework and experiential learning modules. We will precipitate skill development over and above technical preparation by interweaving planned experiences with peers and senior members of corporate, civic and professional organizations.

A brief description of each program component is as follows.

- **General Education**. The general education component will include fundamental courses in communications, humanities, arts, history, and political science. This component fulfills the general education requirements of the University and sets the foundation and context of critical inquiry for the remainder of the curriculum. Students will know and understand the importance of a liberal education and its basic tenets; the pursuit of truth and access to knowledge, intellectual and ethical development of students, and the general well-being of society. Undergraduate students must be broadly educated and technically skilled to be informed and productive citizens [19]. As leaders in engineering, they will need to be able to think critically about significant issues. Students also need to be prepared to complete undergraduate work (the steps ahead, above and around the corner) and their engineering topics and track. The general education requires a high level of knowledge about and competence in the following areas: communication, computer use, mathematics, problem solving, natural sciences, social sciences, humanities, and arts. Thus the mission of general education is to provide undergraduate Leadership Engineering students with a structured base through which these needs can be met [19].

- **Science and Mathematics**. ABET accreditation requires at least 30 credits of science and math topics in the curriculum. We will utilize a just-in-time, applied mathematics approach to accelerate the calculus knowledge so students may enter engineering courses early in the curriculum. The mathematics requirement will include statistics, and the science requirement will include life science in addition to the usual physical science topics.

- **Engineering Topics**. ABET accreditation requires at least 45 credits of engineering topics, including engineering science and design. The engineering science topics will include those required for the Fundamentals of Engineering exam, including computing fundamentals, materials science, mechanics (solid and fluid), materials, thermodynamics, electronics and electromagnetic applications. The engineering science topics will also include a short track of courses in a specific engineering discipline, to prepare the student for further professional graduate education in that discipline. Finally, this component will provide a design practicum "spine" to the curriculum that will begin the first year and culminate in the fourth year with a major design experience. The design practicum will include concepts in creativity, innovation, and entrepreneurship. Thus, we anticipate a roughly 50-50 split between engineering science and design topics in this component.

- **Management Track**. The core component for the Leadership Engineering program will reside in what we are calling the management track. The management track will prepare future graduates with skills for financial, human resources, and project management, along with the ability to formulate problems, integrate knowledge, and think critically. Faculty from programs in the Colleges of Business Administration and Liberal Arts will work very closely with faculty from the College of Engineering to develop coursework in the areas of finance, management, entrepreneurship, ethics, anthropology, decision sciences, and technology-based critical inquiry.

- **Education Track**. For students whose intent is to enter into K-12 education following the bachelor's degree, the management track will be replaced by the education track. Students will take courses in the College of Education to complete the necessary training for teacher certification. The track will provide graduates with the necessary experiences and credentials to lead engineering education advancement, important to the future of the US, in so many ways [6].

- **Entrepreneurship Track**. We anticipate that a significant number of students attracted to this program may pursue business start-ups upon graduation from the program or soon thereafter. For students with this strong interest, the management track will be replaced by the entrepreneurship track. Faculty from the Colleges of Engineering and Business will work together to develop coursework in entrepreneurial practice, technology innovation, venture development, venture law, intellectual property, and engineering economics.

## IV. Market for Leadership Engineering Graduates

We agree with Duderstadt [1] and King [9] that a transition to the recommendation by the *Engineer of 2020* [4] to the master's degree as the first professional degree in engineering will be difficult and will thus need to be gradual. What we are striving to achieve is a transformative engineering education [20]. In step with leading engineering education institutions [21], we are moving forward to provide educational experiences that develop students' knowledge areas, abilities, and qualities to enable them to take a leadership role in identifying needs and constructing effective solutions in a diverse, economically, socially and relevant manner.

Through Leadership Engineering we seek to provide a nurturing environment, a tailored engineering program, and unique interdisciplinary experiences for undergraduate students to lead and succeed at the interfaces of traditional disciplines and to prepare graduates to become leaders in a rapidly changing and increasingly multidisciplinary engineering profession. This holistic approach is akin to that of forward-looking engineering programs, and matches closely to the mission of noted leading-edge multidisciplinary engineering education programs, such as that at Purdue University [22].

We believe the appropriate first step in this direction is the creation of a broad-based, liberal engineering program that will eventually feed graduates into professional master's degree programs, but will also offer other viable opportunities to graduates of the program to fill a current market need.

### *A. Professional Graduate Programs*

Many professional graduate programs already exist for which the described program would be suitable preparation. These programs are typically interdisciplinary in nature and are targeted to specific market niches. Examples that are currently offered or in the planning stages at UTEP include systems engineering, information technology, construction management, manufacturing engineering, software engineering, materials engineering, biomedical engineering, computer engineering, engineering management and environmental engineering.

The long term (5-10 years) plans at UTEP are to design and implement formal professional graduate (master's) programs that will seek ABET accreditation. The programs will require 36-semester credit hours, at least six of which will be practical experience via internship or other similar modality. The other thirty hours will be focused on engineering science topics appropriate to the discipline, and will build on the coursework from the undergraduate engineering topics component. Since students in these programs will now be educationally more mature, and have the "learning-how-to-learn" foundation from the Leadership Engineering program, the coursework will have more depth and resonance than if the students were taking similar coursework at the BS level in a traditional program.

So in essence, by 2020, we plan to achieve the combined recommendations of the *Engineer of 2020* [4] and *Engineering for a Changing World* [1] for the optimal education of engineers – a broad-based, liberal undergraduate engineering degree program followed by an accredited, graduate professional engineering degree program in a specific discipline.

### *B. Technology Services Industry*

There are several megatrends shaping the global economy. Prominent amongst them are globalization, digitization, deregulation and privatization, changing demographics, commoditization of processes, and the increasing impact of emerging economies [23]. The service sector not only improves competition in every national economy and helps to advance employment figures, but it generates more than 80% of jobs in the US [11]. The technology services industry is thus a ready-made large market for graduates of the Leadership Engineering program. Based on the data provided earlier, along with an increasing amount of anecdotal data we have from discussions with technology service industry members, there is tremendous need for graduates from the Leadership Engineering program, and for graduates who would then go on to professional master's programs in information technology, software engineering, computer engineering, or systems engineering, for example.

### *C. Entrepreneurship*

From earliest days, growth of the U.S. economy has been inextricably tied to technological innovation. What have changed over time are the fields of innovation, the institutions carrying out the work, and the environment that provides the driving forces for change. What has remained constant is the key role of scientists and engineers in the process [24]. The prominent role that engineers play in innovation has led to their involvement in a much more comprehensive range of issues associated with the development of new products and the growth of technology-based companies. While enormously empowering, these developments place a new set of demands on new graduates. They are expected to have a broader range of skills, a greater sense of teamwork, and an awareness of a wide variety of information [24].

Engineers can energetically launch high-tech companies to move their ideas to the market. Studies show that the majority of innovative products and services in our economy evolve from entrepreneurial ventures [25]. By providing knowledge and skills important to the creation and leadership of such startups, a Leadership Engineering program can recruit and train the founders and leaders of tomorrow's high-tech ventures. Given some individuals attracted to a Leadership Engineering program will likely have, or gain, an interest in starting their own business, the Leadership Engineering program, with the entrepreneurship track, provides a pathway to achieve competencies in the combination of business and engineering skills required by the technology entrepreneur.

### *D. Education*

With the increasing tendency to include STEM career-oriented education in middle and high schools across the country, the need for STEM education leaders, and qualified STEM teachers, having a strong engineering education foundation will also increase. The Leadership Engineering program provides a broad-based engineering foundation with the necessary training for teacher certification and practical experience. The program can produce students who are clinicians, having skills similar in some ways to the Harvard-MIT health sciences and technology graduates [26] but being practitioners focused on STEM and in particular engineering education. These students will have learnt how to address the needs of STEM education, based upon personal experience in the new program. They will know about the start-up, growth, and management of engineering education as an enterprise. The Leadership Engineering program will also be an optimal feeder program for the growing number of graduate engineering education programs in the U.S.

## V. Conclusions and Next Steps

Prestigious and authoritative engineering bodies in the U.S. such as the National Academy of Engineering (NAE), acclaimed academic bodies such as the National Science Board (NSB), professional societies such as the American Society for Engineering Education (ASEE) and a multitude of leading US technical corporations, have spoken unanimously and repeatedly about the need to "reinvent engineering education." Even so, changes in the education experience for undergraduate engineering students, while significant in some respects, have been mostly piecemeal or at the margins for the last forty years.

The large cost of retrofitting engineering programs around the country, along with the burden of reaching a consensus agreement on a single programmatic framework among a diverse set of accreditation, licensing, and professional organizations, presents a considerable, and perhaps insurmountable, barrier to achieve the recommendation of the *Engineer of 2020* by the year 2020.

That is why we are proposing a viable first step in this direction – the implementation of a broad-based, liberal undergraduate engineering program that can not only serve as a feeder program into future professional master's degree programs, but whose graduates also have immediate opportunities in the emerging and burgeoning markets of the technology services industry and in engineering education.

One might also ask whether UTEP is the appropriate institution to initiate this first step in the transition process. The role of the now-traditional public flagship institution has evolved over the last 100-150 years from "education of the masses," to becoming a highly selective institution with an extensive research mission. With the masses, by which we mean our constituent populations, becoming more and more concentrated into urban regions of the country, the regional, urban-based university has now taken on the original role of the long-time flagships. Combining this with the obligation of regional institutions to engage with local industry and public sectors of the region's community, we believe a very strong argument can be made that the transition to the *Engineer of 2020* should begin at regional, urban universities having engaging, comingled teaching and research missions, and having 21st century demographics, such as we have at UTEP.

Our next steps in the development of the program will be to convene an industry advisory board. This board, along with key faculty drivers of the program, will develop an initial set of specific program objectives. Subsequently, from these objectives a set of program learning outcomes will be derived. The next step will be to then design, develop and implement a series of courses that will deliver content and experiences to achieve the learning outcomes. The final step will be to continue innovation based on continuous quality improvement (CQI) principles. We have an ambitious plan to complete this process during the next two years, in order that we can begin recruitment of our first freshman class for the program to start in the Fall 2012 term.

The primary objective of the Leadership Engineering program is to produce graduates who have a strong sense of values, think critically and make connections contextually across disciplines. Leadership Engineers will be known as critical thinkers and problem solvers with the creativity and ambition that seeks challenging appointments and fast-paced corporate environments. Graduates will go on to become renowned for their contributions to the nation's workforce need for engineering leaders. Samuel Florman, author of *The Existential Pleasures of Engineering* and *The Introspective Engineer*, states the need for Leadership Engineers very succinctly and to the point: "We live in a technological age, and if our society is to flourish, many of our leaders should be engineers, and many of our engineers should be leaders [27]."

It is time for the engineering profession, and engineering education, to move beyond the purely technical path it is currently on, to a "greater engineering" profession, as suggested by Simon Ramo, co-founder of TRW and a founding member of the NAE, in a speech delivered at the 25th Annual Meeting of the NAE way back in 1989 [27]. He defined greater engineering as a profession "which will come to embrace more of the issues at the technology-society interface," and he encouraged educators to ensure that engineering graduates understand the "social-economic-political systems that will exert decisive influences on what they will be assigned and privileged to do [27]." The Leadership Engineering program is a step in that direction.

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# A New Program in Engineering Leadership

Richard T. Schoephoerster
Peter Golding





## Charles Vest

- NAE President, former MIT President
- When he starting teaching in 1967:
  - How to make first year exciting
  - How to communicate what engineers do
  - How to develop an understanding of business processes
  - How to get students to think about ethics and social responsibility
- Today:
  - Ditto

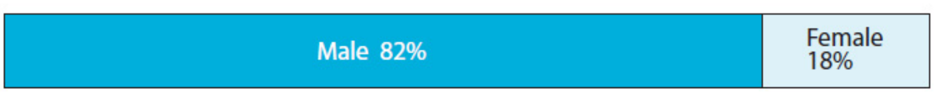
# And now we must add

- Nano – Bio – Info
- Large Complex Systems
- Globalization, Innovation, Leadership
- Teamwork across disciplines, nations, cultures
- Experiential Learning: conceive, design, implement, operate
- Entrepreneurship, Product Development
- Manufacturing, Sustainable Development



Changing the FACE of ENGINEERING

## Bachelor's Degrees by Gender, 2008

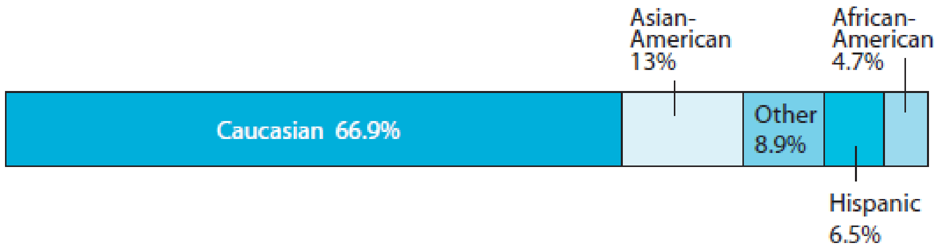



| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| Female | 21.2% | 20.8% | 19.9% | 20.9% | 20.4% | 20.3% | 19.5% | 19.3% | 18.1% |
| Male | 78.8% | 79.2% | 80.1% | 79.1% | 79.6% | 79.7% | 80.5% | 80.7% | 81.9% |

College of Engineering
The University of Texas at El Paso

Changing the FACE of ENGINEERING

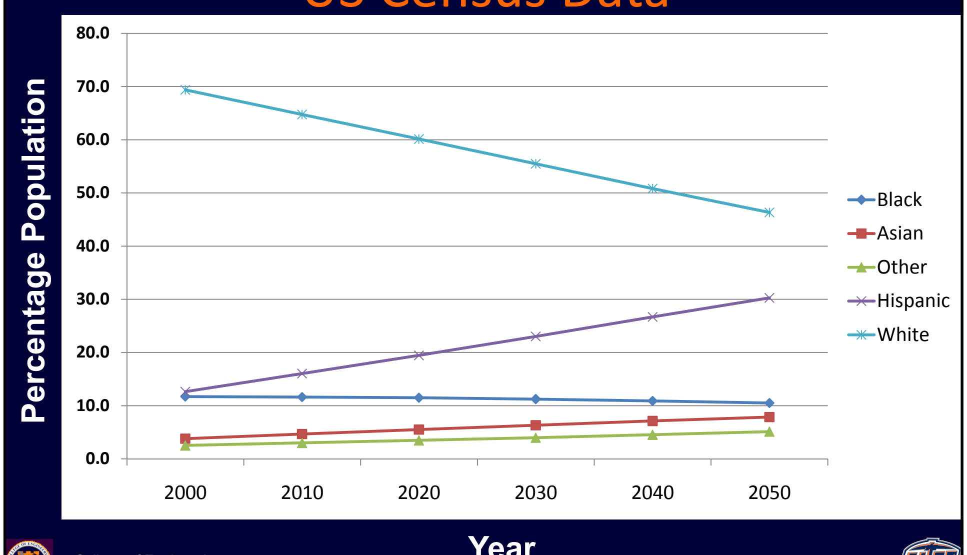
## Bachelor's Degrees by Ethnicity, 2008*




| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| African American | 5.4% | 5.6% | 5.3% | 5.4% | 5.1% | 5.1% | 5.3% | 5.0% | 4.9% |
| Hispanic | 5.8% | 5.8% | 5.4% | 5.5% | 5.4% | 5.6% | 5.8% | 6.0% | 6.2% |
| Other | 10.4% | 8.5% | 9.0% | 7.3% | 7.2% | 8.0% | 8.6% | 8.5% | 8.3% |
| Asian American | 12.5% | 13.1% | 14.1% | 14.2% | 14.0% | 14.2% | 14.1% | 13.8% | 13.3% |
| Caucasian | 65.9% | 67.0% | 66.2% | 67.6% | 68.3% | 67.1% | 66.2% | 66.7% | 67.3% |

Changing the FACE of ENGINEERING

## US Census Data



## Call for Change

- 2000: ABET Engineering Criteria 2000
  - From content to learning outcomes
- 2004: NAE Engineer of 2020
  - Broad undergraduate engineering education
  - MS as first professional degree in engineering
- 2008: ABET accreditation at BS and MS





## Engineering for a Changing World

- James Duderstadt
  - Dean, President, U. Michigan
  - Report published 2008
  - Transformation of engineering practice, research, education
- Medical school model, renaissance engineer
- Leadership as a basis for engineering education
- Graduate professional schools of engineering offering post-BS practice-based degrees
- Liberal, broad-based BS degrees

# Transition Model

- How do we transition from current technical-based BS degrees to broad-based BS degree + practice-based MS degrees?
- Is there a market for graduates of a broad-based BS degree in engineering?
- Recruitment mismatch
  - Industry leaders: broad skills
  - Campus recruiters: specific technical skills



# Market Requirements

- Technology services sector
  - Largest growth sector in US, world
  - IBM, AT&T, HP, Accenture, EDS
  - Combination of skills in addition to CS and Engg:
    - Management, business, legal, cognitive, social
- Engineering Education
  - K-12
  - Graduate programs in engineering education

Changing the FACE of ENGINEERING

# Engineering Leadership Programs

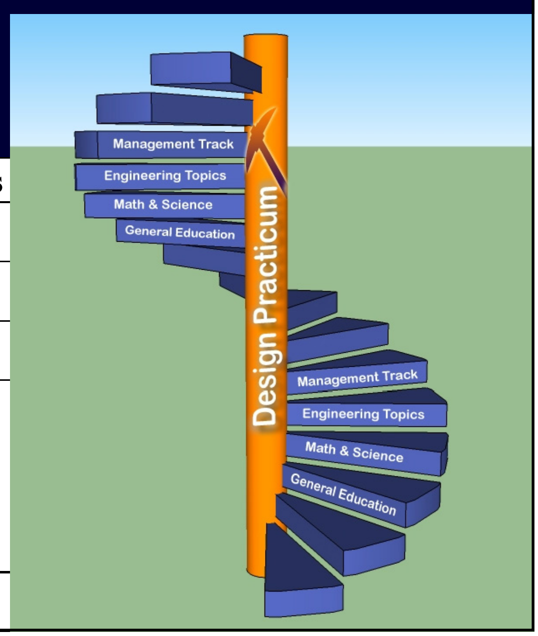
- Common BS degree program goal
  - Produce engineers that will be leaders
  - Very little curricular content
- Usual training: MBA or industry programs
- New trend
  - Extracurricular (project-based)
  - Adjunct (course or minor) to BS curriculum
- Our goal: attract leaders, produce engineers



Changing the FACE of ENGINEERING

# Leadership Engineering

| Component Title | Credits |
|---|---|
| General Education | 27 |
| Science/Mathematics | 30 |
| Engineering Topics | 45 |
| Management Track<br>or<br>Education Track<br>or<br>Entrepreneurship Track | 18 |
| **Total Program** | **120** |



## Component Descriptions

- General Education
  - communications, humanities, arts, history, and political science
- Science and Mathematics
  - Biology and statistics
  - Just-in-time, applied math approach to calculus
- Engineering Topics
  - FE topics (50%), Design & Innovation (50%)





## Component Descriptions

- Management Track
  - Leadership skills
  - finance, management, entrepreneurship, ethics, anthropology, decision sciences, and technology-based critical inquiry
- Education Track
  - K-12 teaching credentials
- Entrepreneurship Track
  - entrepreneurial practice, technology innovation, venture development, venture law, intellectual property, and engineering economics

# Market for Leadership Engineers

- Professional Graduate Programs
  - Master's in Professional Engineering (MPE)
- Technology Services Industry
- Entrepreneurship
- Education
  - K-12
  - Graduate Engineering Education Programs



# Conclusions

- Time is now?
  - emphatically yes!
- Place is UTEP?
  - why not!
  - Flagship vs Urban Regional Institution

Changing the FACE of ENGINEERING

# Final Thoughts

- Simon Ramo
  - Founder TRW, founding member NAE
  - “Great Engineering”
  - issues at the technology-society interface
- Samuel Florman
  - Engineer and author (The Introspective Engineer)
  - “We live in a technological age, and if our society is to flourish, many of our leaders should be engineers, and many of our engineers should be leaders”