THE UNIVERSITY *of* TEXAS SYSTEM

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Task Force on Engineering Education for Texas in the 21st Century

FINAL REPORT

December 2013

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Preface

Chairman Paul L. Foster
The Board of Regents
The University of Texas System
Ashbel Smith Hall, Suite 820
201 West 7th Street
Austin, Texas 78701-2981

Dear Chairman Foster:

The Task Force on Engineering Education for Texas in the 21st Century is pleased to present its report, which examines current and future needs for engineers and computer scientists in Texas and assesses how The University of Texas System institutions can best meet the state's needs.

Engineers and computer scientists are critical to the development and implementation of advanced technologies in Texas businesses and medical enterprises. The Texas Workforce Commission estimates that Texas will require nearly 88,000 more engineers and computer scientists in the current decade, or approximately 9,000 new, well-qualified engineers and computer scientists each year. Texas colleges and universities fall short of meeting the current need, let alone the increasing demand.

The essential finding from this study is that the U. T. System can lead Texas in securing future economic vitality by addressing the need for more engineers and computer scientists. The report makes five recommendations:

1. U. T. System institutions should enroll and graduate more engineers and computer scientists, increasing annual degree production substantially within a decade.
2. The U. T. System and its institutions should inform, inspire, and empower more young Texans to pursue college degrees in engineering and computer science by enhancing the K-12 pipeline.
3. U. T. System institutions should all develop even stronger interactions with industry through various strategies, including leading development of innovation clusters in key regions, expanding internship and co-op programs, establishing a more significant industry-focused presence in Houston, making industry engagement in the instructional and research missions a key priority, and revamping intellectual property policy guidelines for industry-sponsored research. Each institution should establish a stretch goal for the percent of its research that is industry funded.
4. The research capability of our institutions should be encouraged and funded to investigate ways to gain more value from University Lands, thereby accelerating growth of the Permanent University Fund.
5. The U. T. System should brand this initiative to tie together the elements and convey the message nationally that Texas is committed to producing the highest quality engineers and computer scientists.

The U. T. System uniquely possesses the assets necessary to implement the recommended initiatives. Though implementation will require long-term investment, monitoring, assessment, and accountability, its success will attract significant private funding as well as reap great benefits for the State of Texas.

Please feel free to call on any or all of us if we can be of assistance.

Respectfully submitted,
Members, Engineering Task Force

Executive Summary

In late 2012, The University of Texas System convened a Task Force to examine the challenges and opportunities related to engineering education in Texas in the 21st Century. The Task Force members included engineering deans of the U. T. System institutions, individuals from industry, academic leaders, and members of the U. T. System Board of Regents. This report summarizes the results of the Task Force's work.

Texas is an economically vibrant, growing state. Engineering is among the highest paid college degrees: U. T. offers very special low-cost pathways for Texas students to this lucrative and rewarding career. However, the Texas Workforce Commission projects that Texas will need 88,000 more engineers and computer scientists during the current decade. This means nearly 9,000 additional engineers and computer scientists must join the workforce each year or Texas will cease to be as attractive to business. To help meet this critical need in Texas and control our own destiny, the following key elements must be addressed:

- The pipeline of motivated students graduating from Texas high schools who are well-prepared to pursue a college degree in engineering must be strengthened.
- Industry must play a vital role in partnering with universities, and vice versa. Certain obstacles, such as realities and perceptions related to intellectual property, must be addressed, and opportunities, such as more internships and co-op programs, must be acted upon.
- Houston, the nation's "Energy Capital," is Texas' largest city and is responsible for about one-third of the economic output of the state, yet the U. T. System has no academic presence to help address the large local need. Deeper engagement of U. T. System institutions in the region will tap into Houston's large pool of industry talent, knowhow, and research efforts. Additionally, a crown jewel of Houston is the Texas Medical Center, which offers significant opportunities in biomedical engineering focused on improving the human condition.
- Demand for more engineers and computer scientists is both near-term and long-term, calling for quickly adaptable solutions as well as long-term investments.

The Task Force recommends that the U. T. System launch one of the most significant initiatives in engineering education advancement in the United States. The needs are big, the required investments are large but reasonably fundable, and the payoff for Texas and future students in the System is enormous. The Task Force specifically makes five recommendations:

1. Expand the production of engineers and computer scientists in Texas, and graduate at least 50% more students per year within a decade. Each institution within the U. T. System has developed a preliminary plan for expansion. As part of this expansion, numerous opportunities exist for collaboration among U. T. System institutions and for new approaches such as leveraging the U. T. System Institute for Transformational Learning. U.T. Austin has proposed a plan to expand capacity by 20% to increase undergraduate enrollment by 1,000 students. Other institutions in the System must develop additional industry-savvy strategies for attracting an increasing share of the top students and placing them with the most prestigious employers.
2. Motivate and inspire more young Texans to pursue engineering careers by strengthening the K-12 pipeline. Key initiatives include expanding science and math teaching capability via UTeach programs, engaging students in summer programs conducted collaboratively with industry, and utilizing online tools specifically aimed at helping Texans develop essential math skills.
3. Engage industry in mutually-beneficial partnerships through greater use of internships and co-op programs, more proactive engagement of industry in the research mission of institutions, and establishment of an industry-oriented, multi-institution educational platform in Houston.
4. Yield more value from University Lands by putting the research capabilities of U. T. faculty and students to work on maximizing the value of hydrocarbons from these lands. This will accelerate the growth of the Permanent University Fund as well as seed and support invaluable research and human resource development.
5. Brand this overall initiative, which would constitute historic growth and enhancement of engineering education in Texas. The initiative would represent a tremendous competitive advantage for Texas as it recruits and grows highly successful companies, big and small, who need engineering and computer science expertise and entrepreneurship to be successful in this technologically-intense, globally-competitive economy.

Implementation plans should include benchmarks and accountability metrics. The cost of the recommended initiative is significant but is believed to be reasonably fundable over time. The return on investment is estimated to be many orders of magnitude greater than the U. T. System investment.

Charge to Task Force

The State of Texas maintains a vibrant economy by creating new jobs and attracting companies that compete on a national and global scale. Texas is a leader in the number of Fortune 500 companies headquartered in the state, with more large companies continuing to establish roots here. The engineering and computer science sectors, in addition to contributing to the state's economic vitality, also support national security and the health and quality of life for Texas citizens. Texas is also widely known as "the energy state" because of its cutting-edge technology capabilities across all aspects of energy development, particularly hydrocarbon energy sources.

In order to maintain this competitive edge in the future, it is important to determine if the higher education system in our state has the capacity to produce the quantity and quality of trained engineers and computer scientists needed to support the increased workforce demands associated with the state's continued economic growth. Texas offers much to businesses throughout the state and cannot afford to be handicapped by a lack of critical engineering talent in the workforce. Success in the field of engineering and computer science will better position Texas as a leading innovator for the future, which will ultimately benefit the citizens of Texas, our nation, and the world.

Appointed by The University of Texas System Board of Regents then Chairman Wm. Eugene "Gene" Powell and U.T. System Chancellor Francisco G. Cigarroa, M.D., the "Task Force on Engineering Education for Texas in the 21st Century" was created with the goal of assessing the current state of engineering degree programs in Texas, better understanding the current and future demand for engineers, and identifying strategies for the Texas Legislature and higher education leaders that will foster student success in the field of engineering, while at the same time support economic growth across the state. As the Task Force began its work, it became clear that computer science and engineering are inextricably linked and, thus, the Task Force considered them collectively.

Texas has led the nation in economic growth over the last several years, and economists forecast a continued increase in demand for engineers and computer scientists, creating a continuous need for well-trained specialists across various disciplines. Task Force members were charged with reviewing and identifying key issues related to demand, capacity, efficiency, supply, and research related to engineering programs in Texas, how these issues affect Texas and the nation, as well as what the U. T. System can do to be responsive to students' needs and workforce demand.

During this study, Task Force members were specifically asked to consider the following:

- Current and future demand for undergraduate and graduate engineers over the next 25 years.
- Current engineering education capacity for undergraduate and graduate students at U. T. institutions and how that compares with the need.
- How Texas engineering schools can better collaborate and coordinate their efforts, facilities, faculty, and strengths to more efficiently and effectively meet the demand for engineers.
- How to prepare and attract K-12 students to engineering programs.

The Task Force consists of both academic and business experts in the field of engineering. Task Force member biographies are available for review in **Appendix A.**

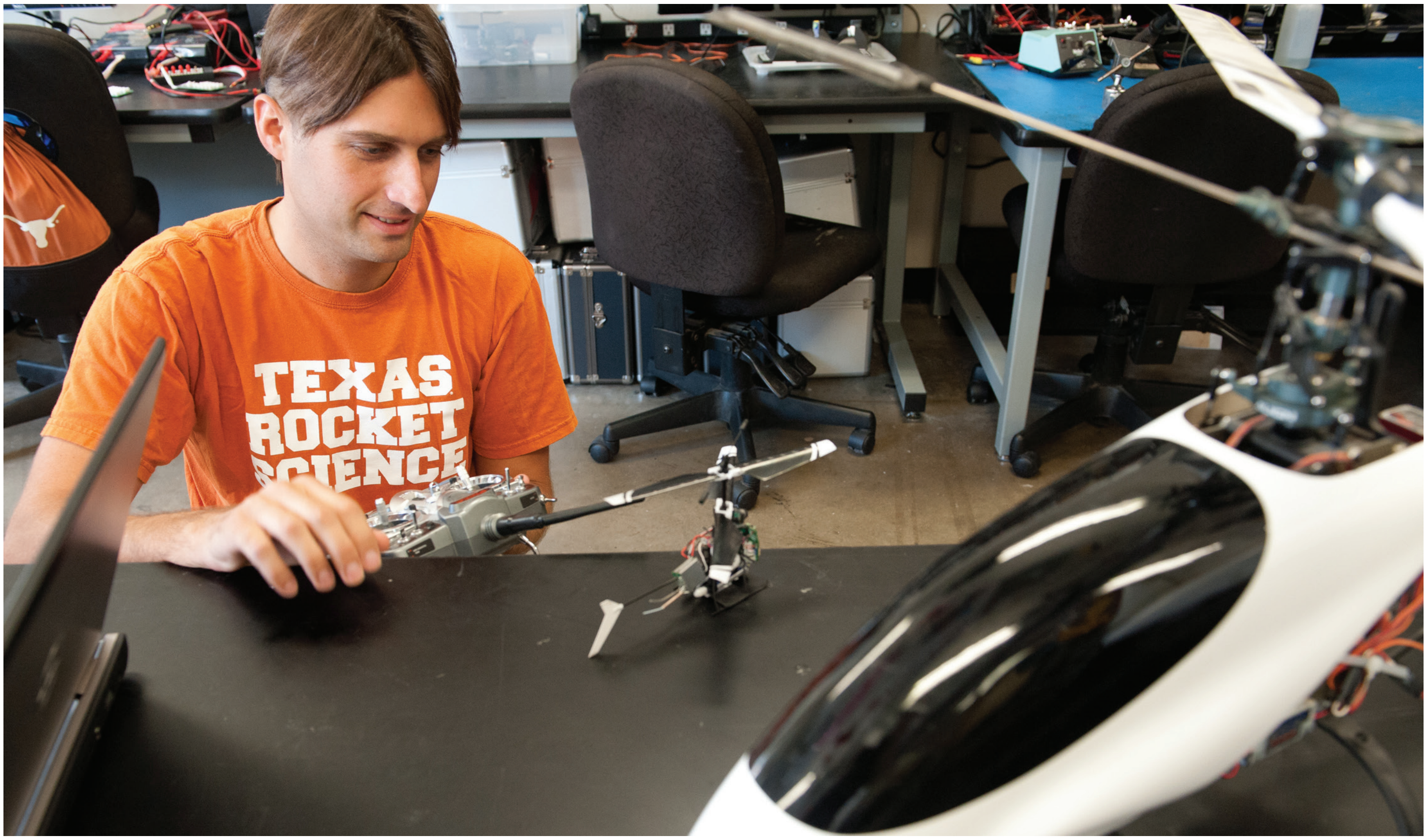
Task Force Process

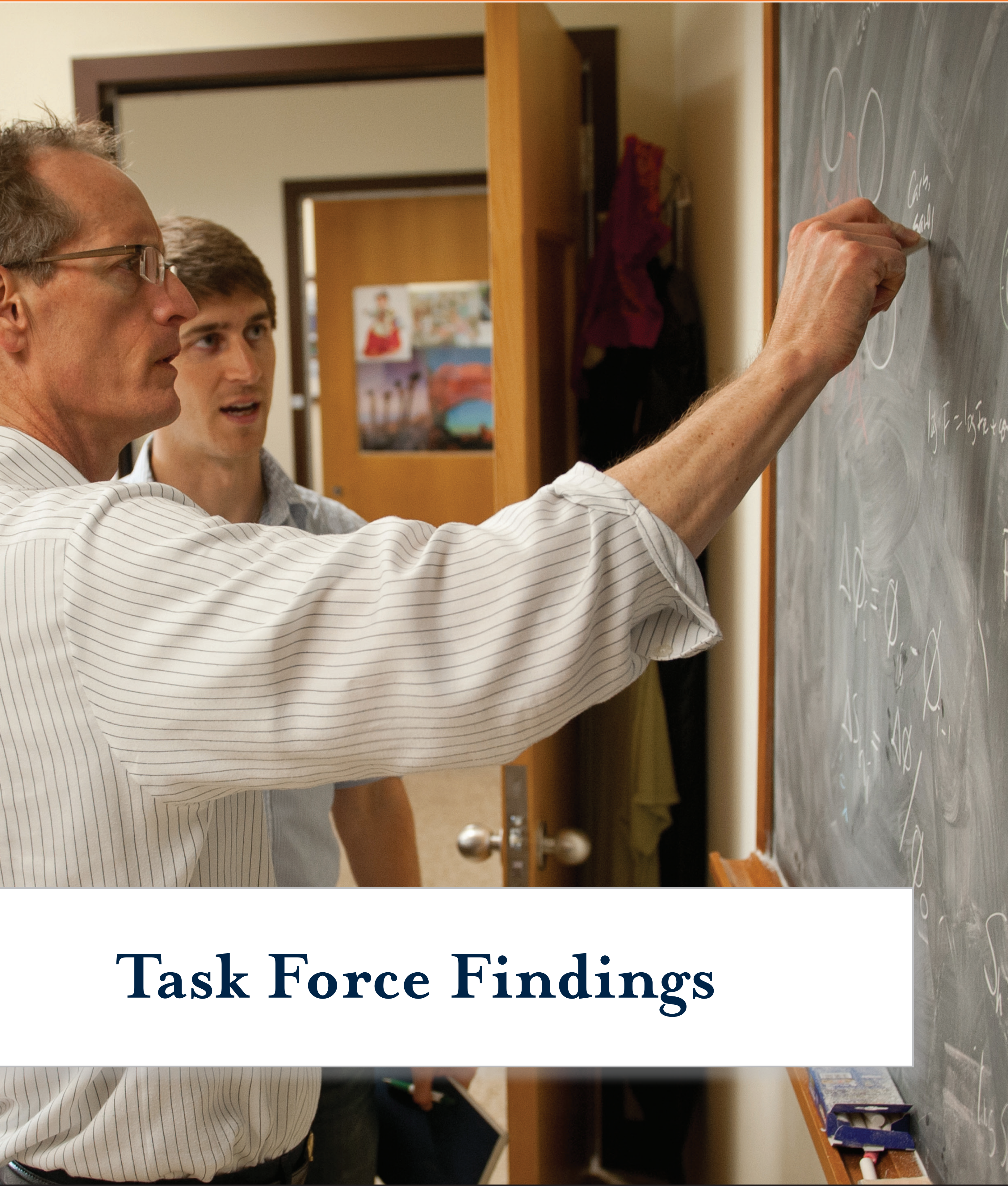
The Task Force began its work in late 2012 with the goal of delivering a report to the U. T. System before the end of the 2012-13 academic year. The initial meeting was a telephonic conference call to discuss goals and process.

Five all-day, face-to-face meetings were held in Austin from January through June 2013. These meetings centered on discussions among Task Force members and frequently included guests who were invited to address specific topics, such as what industry is seeking from graduates of U. T. System institutions, how to better engage industry in university research, how intellectual property is managed, and what other Texas institutions are doing to expand the production of engineers. Additionally, many conversations took place among Task Force members and others to explore various topics of interest, such as co-op programs.

The Task Force also formed several sub-groups to explore specific topics in depth, such as "pipeline" issues in K-12 education, needs and opportunities in the Houston area, potential new degree programs, and strategies to increase output from U. T. System institutions.

Much analysis was conducted to generate data needed to support the Task Force's work. Dr. Stephanie Huie (Vice Chancellor for Strategic Initiatives for the U. T. System), supported by Dr. Larry Redlinger (U. T. Dallas) provided the needed data. Much data collection and analysis was conducted by Dr. Pedro Reyes (Executive Vice Chancellor for Academic Affairs for the U. T. System) and his staff. Stephanie DeLeon in the U. T. System Office of Academic Affairs helped coordinate meetings and information dissemination. Meg McConnell (Consultant) assisted in preparation and editing of this report. Dr. J. P. Bardet and Dr. David A. Allen, two former engineering deans and Task Force members, contributed to the process. Dr. Gregory L. Fenves was Dean of the Cockrell School of Engineering at U. T. Austin during much of the Task Force's work and was appointed Executive Vice President and Provost at U. T. Austin in Fall 2013. Dr. Fenves continued to provide valuable input to the Task Force's work even after his period of service as Dean was completed. The support and contributions of each of these individuals is gratefully acknowledged.





Task Force Findings

Overall Findings

Key overall findings of the Task Force are summarized as follows.

1. In terms of engineering and technology, Texas is nationally and internationally known as "the energy state," particularly with regard to hydrocarbon energy sources.

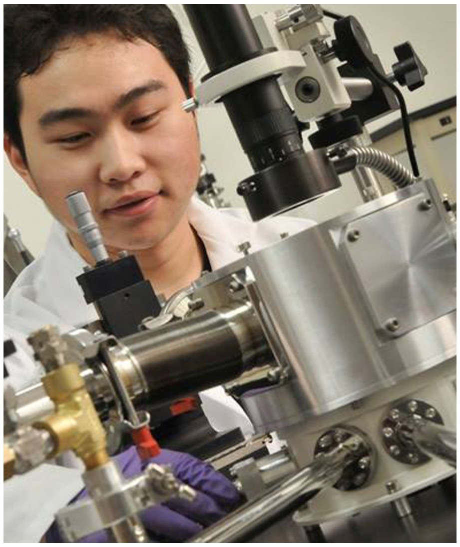
The role of Texas in terms of energy production in the United States is widely recognized. Some statistics[1] about Texas' energy production include the following:

- Texas is the leading crude-oil producing state in the nation, with production in 2011 exceeding that of all offshore oil production on federal lands.
- In 2011 Texas' oil refining constituted 27% of all the refining capacity in the United States.
- Texas also accounted for 28% of all natural gas production in the United States in 2011.
- Texas led the nation in wind-powered energy in 2010 and was the first state to reach 10,000 megawatts of capacity.

The Houston area is considered to be the "Energy Capital of the World," and one of the key global locations for hydrocarbon energy exploration, production, and refining. The high concentration of engineers, scientists, research, and technology development centers for the oil industry and the vast array of specialty support companies give the Houston area an unmatched edge in technology and infrastructure compared to virtually anyplace else in the world. The Houston-based Texas Medical Center, in particular, provides significant additional opportunities in the field of engineering.

The focus on energy in Texas is supported by the U. T. System engineering schools' graduates, who supply talent to these companies. Currently, an estimated one-third of U. T. Austin's engineering graduates work in the energy sector.

Additionally, recent technological advancements have created expanding oil and gas production in both Texas and the United States as a whole, which creates a significant benefit to the state economy as well as a high, growing demand for more engineers. Many believe that the large quantities of relatively low-cost hydrocarbon fuels that will be extracted from previously non-productive Texas lands will result in unprecedented expansion of manufacturing in Texas, and expansion of related support industries. Thus, the "boom" in the energy sector not only demands more engineers and computer scientists directly in the energy sector but also indirectly in numerous other sectors of the economy that will grow as a result of the energy advantage of Texas.



2. Engineers are critical to the well-being of Texans and to maintaining a vibrant, globally competitive state economy.

Engineers are known for their ingenuity and ability to develop new processes and products that haven an impact on a wide range of industries like technology, health care, and manufacturing. According to Bordogna[2], "The true strength of a nation resides in its human capital—especially its engineering workforce,…[who] put knowledge to work for society and facilitate the private sector's potential to create wealth and jobs." Engineer-entrepreneurs, especially in the energy and high-tech sectors, founded significant shares of Texas' new companies.

[1]Source: UNITED STATES Dept. of Energy, http://www.eia.gov/state/?sid=TX

[2]Source: "Making connections: The Role of Engineers and Engineering Education," The Bridge, National Academy of Engineering, Washington DC, 1997.

3. A clear need exists for more high-quality engineering graduates from Texas colleges and universities.

The Texas Workforce Commission[3] estimates that the demand for engineers and computer scientists in Texas will increase significantly in the next seven years, requiring nearly 88,000 more engineers in 2020 than in 2010. Of these additional engineers, 59,000 will be needed in computer software and systems fields. This workforce need means Texas schools should be producing about 2,900 additional engineers each year and 5,900 additional computer scientists and computer support specialties each year (for a total need of nearly 9,000 more employees each year) to keep pace. Presently, Texas public universities graduate approximately 10,000 computer scientists and engineers annually[4]. The needed increase of 9,000 degreed individuals per year means that Texas needs to nearly double its annual production of computer scientists and engineers to meet workforce needs. Certain industries, such as the oil and gas industry, are entering a period with a high rate of retirement, further aggravating the problem of too few engineers and computer scientists.

Among the engineering fields, the largest workforce needs will be petroleum engineers, electrical/electronics and computer engineers, civil engineers, mechanical engineers, and industrial engineers. Technologies and business opportunities may shift over the time scale of a decade or more; however, engineers are adaptable to changes in technology and manpower needs. In addition to needing more engineers, Texas needs more licensed professional engineers.

In Texas, the need for engineers is growing faster than the national average, at a staggering 21% each year, almost double the national average of 11% annually[5]. Another indicator of the growing need for qualified engineers in our state is the high starting salaries for new graduates in the engineering field. The Task Force strongly believes that this need will continue to grow, and that the key issue is how the System can best accommodate that demand in a timely and proactive manner.

In thinking about how Texas might meet its needs for engineers, the State should think about "growing its own" from within the ranks of Texas citizens, or "importing" engineers from other states or countries. The demand for engineers is determined by business needs as well as retirements or other departures of engineers from the current Texas workforce. The supply comes from within the state and externally, as well.

One could argue for importing the much-needed engineering talent, and that is precisely what industry will do if it cannot meet its needs locally. Texas then becomes a much less attractive place for business if it cannot find the necessary workforce locally. Further, as will be seen in the next section, there is tremendous individual benefit for Texans who obtain engineering degrees, and one of the purposes of public institutions like the U. T. System is to benefit the citizens of the state. Thus, the logic for attempting to meet as much of the demand for more engineers as possible from graduates of U. T. System institutions is: (1) to provide a local supply of necessary human talent that will attract businesses to Texas, and (2) to benefit citizens of Texas. Texas residents would otherwise either be prevented from gaining access to an engineering career or be forced to pay high out-of-state tuition and leave Texas for their studies. The Task Force believes that these reasons should compel the U. T. System to meet as much of the Texas demand as possible.

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[3]Source: U. T. System, Workforce Demand, p. 10.
[4]Source: Texas Higher Education, Coordinating Board, http://reports.thecb.state.tx.us/approot/dwprodrpt/gradmenu.htm
[5]Source: U. T. System, Workforce Demand, p. 9.

4. The individual, in addition to society as a whole, benefits from an engineering degree, which adds to a graduate's lifetime earnings.

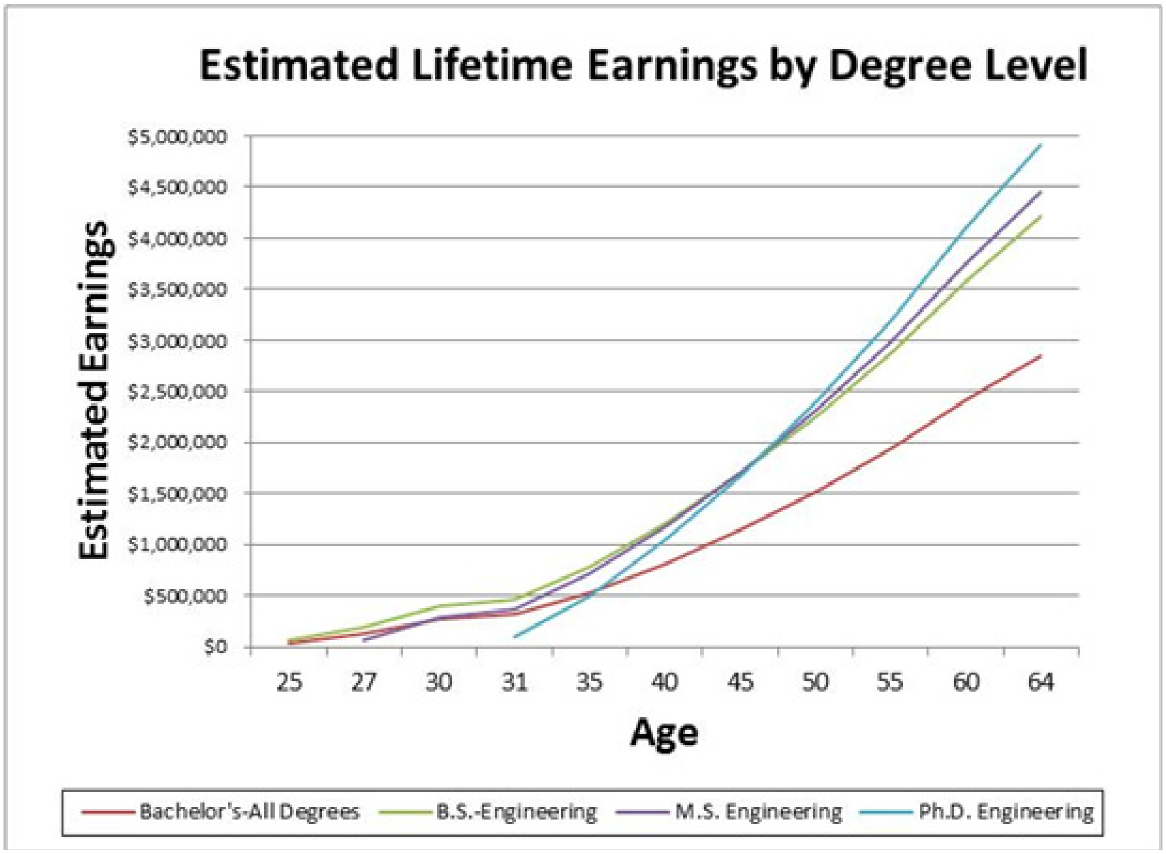
According to the United States Census Bureau, work-life earnings are related to educational attainment as follows[6]:

- High school diploma: $1.37 million
- Bachelor's degree (all types): $2.44 million
- Bachelor's degree (engineering): $3.35 million
- Master's degree (engineering): $3.92 million
- Doctorate degree (engineering): $4.18 million

The value added to estimated lifetime earnings by level of degree is significant. Estimated lifetime earnings are based on years of employment with a 2.5% increase in salary assumed each year for individuals receiving bachelor's degrees. Years of employment is assumed to vary based on degree level (bachelor's: 40 years; master's: 38 years; and Ph.D.: 34 years). Starting salaries are based on 2006-2011 data, the U. T. System graduating cohorts' first-year earnings by degree type, and degree level based on wage records from the Texas Workforce Commission.

As seen in **Figure 1**, the difference in total lifetime earnings in Texas increases substantially based on the graduate's degree type and level.

Figure 1: Estimated Lifetime Earnings by Degree Level.



[6]Source: Handout from the U. T. System for engineering degrees; http://www.census.gov/prod/2012pubs/acsbr11-04.pdf for the other two data points.

When listed in dollar amounts, like in **Table 1** below, the difference in lifetime earnings becomes even more concrete. The higher first year of earnings alone may encourage potential engineering majors to recognize the value of an engineering degree in both the short and long term.

Table 1: Estimated Lifetime Earnings by Degree Level.

	U. T. System Institution Graduates		National Survey of Recent College Graduates[7]	
Degree	Median First Year Earnings (inflation adjusted for 2012)	Estimated Lifetime Earnings	Median First Year Earnings (inflation adjusted for 2012)	Estimated Lifetime Earnings
Bachelor's – All Degrees	$42,175	$2,842,706	---	---
B.S. Engineering	$62,517	$4,213,795	$57,910	$3,903,282
M.S. Engineering	$71,453	$4,446,348	$70,545	$4,389,825
Ph.D. Engineering	$93,488	$4,918,666	$78,969	$4,154,787

The data illustrate several important findings:

- A degree in engineering or computer science from a U. T. System institution has great value for the degree recipient in terms of both initial and lifetime earnings.
- A bachelor's degree in engineering produces a substantial lifetime earnings increase compared with other bachelor's degrees. Considering lifetime earnings, a B.S. in engineering relative to other bachelor's degrees contribute an additional $1.3 million in earnings. When comparing national first-year median earnings, U. T. System engineering degree recipients make more than $4,000 more dollars their first year in the workforce.
- A M.S. degree in engineering adds a modest increase in estimated lifetime earnings compared with a B.S. in engineering. There is not a significant difference in first-year earnings for individuals receiving a master's degree in engineering when comparing Texas earnings versus national earnings.
- In general, a Ph.D. degree in engineering from a U. T. System institution does add a substantial increase in estimated lifetime earnings when compared to B.S. and M.S. degrees in engineering (an additional $704,871 and $472,318, respectively). Individuals who obtain doctoral degrees within from U. T. System institutions produce a substantial lifetime earnings increase compared with other national Ph.D. engineering recipients. Moreover, a Ph.D. degree in engineering is valuable in other ways, such as contributing to the advancement of the frontiers of knowledge and training individuals for research laboratories and academia.

The National Association of Colleges and Employers reports that in 2012, eight of the top 10 paying majors were in engineering or information/computer science, including (in descending order of starting salary): computer engineering, chemical engineering, computer science, aerospace engineering, mechanical engineering, electrical engineering, computer engineering, and information sciences and systems.

Additionally, Forbes magazine[8] identified the most valuable college majors considering salary and overall career prospects through 2015. Of the 10 top majors, six are in engineering or computer science. The most valuable majors, in descending order, are: biomedical engineering, biochemistry, computer science, software engineering, environmental engineering, civil engineering, geology, management information systems, petroleum engineering, and applied mathematics.

Overall, it was noted that engineering graduates earning a bachelor's degree tend to earn the highest salaries of all fields. This is important because as U. T. System institutions consider student-focused investments, engineering is an area with great benefit to both the student and the Texas economy.

[7]Source: National Survey of Recent College Graduates (NSRCG), Public; SESTAT Data Tool.
[8]Source: http://www.forbes.com/sites/jennagoudreau/2012/05/15/best-top-most-valuable-college-majors-degrees/

5. While many engineering schools within the U. T. System are significantly engaged in industry-sponsored research, there is a need for greater engagement, and some obstacles must be addressed.

In 2011, U.T. System engineering schools had $319 million in research expenditures, of which $155 million came from the federal government and $56 million from business and non-profit organizations. Only $36 million, or about 11% of the research total, came directly from industry. Overreliance on federal research dollars may distort research priorities Systemwide at the expense of topics important to Texas but less critical to funding agencies in Washington D.C.

When U.T. System institutions work with companies to develop strategic research relationships with faculty, both the company and the institution benefit. Students are excited to work in the industry because they get to understand critical issues and gain real-world experience, as well as build a comprehensive portfolio. Industry benefits from faculty expertise, as well as campus facilities and research teams. At all U.T. System institutions, there are a number of students who are engaged with industry through full-or part-time employment or internships.

Co-op programs (where a student attends school for some semesters and works full-time for some semesters), though quite popular at some universities, are not well developed at any U.T. System institution yet. The Georgia Institute of Technology provides a good example of well-developed co-op and internship programs, which annually provide Georgia Tech engineering students with $25 million of income[9]. Graduates of Georgia Tech's co-op program have been found[10] to:

- Outperform non-co-op students in upper-level coursework and have higher cumulative grade point averages.
- Enjoy greater success in finding a job – between 2006 and 2010 (a difficult economic period for the United States) 77% of co-op students reported finding a job upon graduation compared to 48% of non-co-op students.
- Earn larger starting salaries – co-op students earn a higher starting salary than non-co-op students for all engineering majors, with the increase typically ranging between $1,000 and $5,000 per year in the various majors.
- Have greater career satisfaction – five years after graduation, survey data show that co-op students enjoy greater career satisfaction and have received more career promotions than non-co-op students.
- Take about six months longer to graduate but pay less tuition. Interestingly, students who participate in co-op at Georgia Tech take six months longer to graduate (because they take time off from school for the work assignments), but enroll in fewer school terms to do so, thus saving tuition costs and even earning income ($25 million for the entire program in a single year) to pay tuition and living costs.

Georgia Tech, overall, is deeply integrated with industry not only in its co-op and internship programs but also through regional technology centers, technology commercialization, Georgia Research Alliance, and others.

There are also useful examples of successful industry engagement in large-scale research, such as at Southwest Research Institute (SwRI) in San Antonio. One critical success parameter for SwRI is deep personal engagement of principal investigators working closely with their research sponsors. In academia, professors in engineering are trained and mentored on how to secure research funding that will support pushing the frontiers of knowledge in their field of specialization. They are not trained on how to address a particular company's problem and often do not know how to approach industry. It was learned from discussion with leadership at SwRI that a change in paradigm may be necessary to engage industry in a significant way with U.T. System institutions. The formula for success may be professors who understand, can relate to, and are engaged with industry in exploring issues that are of interest to both industry and academia. Although nearly all engineering schools have some faculty with industry experience, in order to attract more industry-sponsored research, it may be necessary for engineering schools to have even more faculty members with deep industry experience. The critical characteristic to successfully attracting research from industry is

[9]Source: Thomas M. Akins, Executive Director (Retired), Division of Professional Practice, Georgia Tech.
[10]Source: Georgia Tech Office of Assessment, https://www.assessment.gatech.edu/2012/11/16/wace-2012-presentation/.

having principal investigators who understand what industry needs and ask, “What do you need to solve your most pressing engineering problems?”

There are several obstacles to attracting more industry-sponsored research, however. Universities tend to be slow to deliver results (time frames of months to years), whereas industry often wants quicker results targeted towards a specific issue. Industry sometimes wants the information to remain proprietary or confidential, which can be a challenge when students are conducting the research and have an expectation to publish the results in a thesis or dissertation.

Not surprisingly, the most significant barrier to attracting more research from industry appears to be the real or perceived obstacles related to intellectual property (IP). The Task Force spent considerable time evaluating this issue and found it to be complex. From industry’s perspective, industry contributes funding and knowhow for the research and typically expects to own the results or at least be able to access the results under known circumstances. From the university’s perspective, faculty and students may generate discoveries, sometimes based on substantial background and IP, and, therefore, the university should own the intellectual property.

The Task Force notes that industry-sponsored research is becoming more important than ever, particularly with declining federal support. The Task Force believes that there needs to be a fundamental rethinking of the U.T. System’s IP policies. The university’s primary mission is maximization of knowledge and innovation, and production of graduates that our state needs, not maximization of IP control or revenue. There was considerable support for IP policies similar to those being developed by U.T. Austin’s Cockrell School of Engineering, which has been advocating for the granting of a non-exclusive royalty free license for most industry-sponsored research, or even a waiver of IP rights under appropriate circumstances.

The Task Force members believe that the income from more industry-sponsored research, encouraged by more inviting IP policies, will far exceed any lost licensing income. Further, grateful companies (especially entrepreneurs) who benefit from university research tend to be large donors to universities. Protecting IP is also expensive, costing 20-30% of relevant revenue, even including high-value health-related patents.

The Task Force did not consider the situation at U.T. System health institutions, which may face different circumstances than the academic institutions given the much longer development times for drugs compared to electronics or software. Further, the comments noted above are applicable only to industry-sponsored research and are not applicable to federally-sponsored research or to research funded by private gifts.

There is an opportunity for U.T. System institutions to break from the pack with improved IP policies at the U.T. System level, and for U.T. System institutions to become national leaders in attracting industry-sponsored research. The Task Force believes that addressing IP issues at the U.T. System level is very important given the limitations in federally-funded research and the inherent need for engineering programs to connect closely with industry.

Overall, institutions with a diverse portfolio of funding sources seem to thrive most because of cross-fertilization. In these cases all programs benefit, spillover is more likely, and students gain more exposure to different types of projects. The Task Force discussed the possibility of setting institutional goals for industrial research, starting with a minimum of 10% for engineering schools and building to a higher stretch goal. U.T. Austin is currently at about 16% industry-sponsored research, with the rest of the System closer to 13%. Some funding flows through multiple channels and is more difficult to attribute.

When possible, the Task Force also found that in some cases it may be important to have reciprocal relationships in terms of buying products from partners or using industry partners to advise and collaborate on different projects in the future. Encouraging alumni of U. T. System institutions to support research within the System may also be important. Federal research agencies typically have a broadly-announced call for proposals, but industry typically does not, instead focusing on established and reliable partners. Businesses generally have relationships that they leverage, so building a culture of industry-connectedness is key.

In summary, U. T. System institutions all currently work with industry in some capacity. To take those interactions to a much higher level will likely require some fundamental changes, such as:

- More emphasis on internships and co-op programs that directly connect students with industry.
- Hiring more faculty members with experience in conducting research sponsored by industry, and also hiring more visiting and permanent faculty whose industry experience helps to build bridges to industry.
- Addressing real and/or perceived obstacles associated with U. T. System intellectual property policy rules.
- Better educating faculty on how to develop research opportunities with industry.
- Considering incentives for alumni or past supporters of research that encourage them to sponsor more research at U. T. System institutions.

6. The U. T. System's academic institutions and engineering programs are poorly represented in the Houston region.

Even though Houston is one of the nation's largest and most economically-productive cities, and the world's leading city for hydrocarbon energy technology, the System has no permanent academic presence there. While health institutions are well represented in Houston, the engineering field is not. In response to this, in Fall 2013, U. T. Tyler will begin offering undergraduate engineering courses in Houston in collaboration with regional community colleges, addressing an important educational need in the region. The potential to have a greater presence in this market warrants further investigation and consideration, given the current gap in the engineering field. Though expansion would require additional faculty, facilities, and labs, creative options could be considered such as reallocating specialized instructors, incorporating more online teaching, or possibly rearranging course sequencing to give students the flexibility to move through the program more quickly.

The U. T. System has worked to revolutionize education in the Valley, and after careful discussion, the Task Force determined that an opportunity may exist in Houston as well. Houston makes up a third of the economy in Texas, and is the largest metro area in the state without an academic System presence. Because it is in the heart of the petroleum industry, it also boasts great potential for internship and employment opportunities. The Task Force found that the Houston market was largely untapped by the U. T. System and that there is clearly a need not being served by others at this point. Many students who enroll at U. T. System institutions are from the Houston area, and students starting in the local community college system do not have a clear place to go upon finishing their program of study. This business-driven model could leverage the 14 community colleges in the Houston metropolitan area, giving the System an opportunity to pick up where they are ending, starting students at a junior, senior, or master's level.

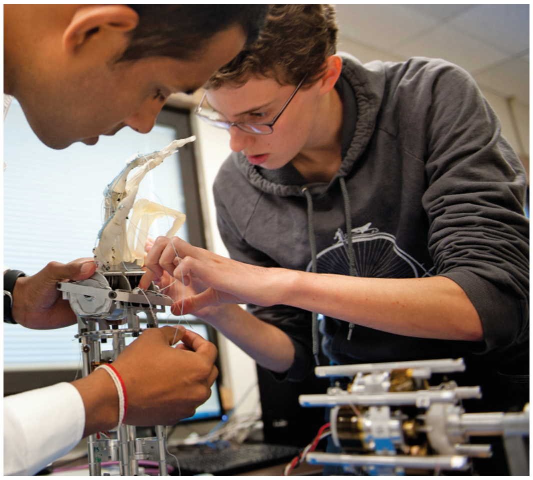
A new physical presence in Houston could also have non-traditional elements associated with it. These elements could be the manner in which classes are offered, the source of the classes (MOOCs and online from other campuses), and could include industry participation in the educational process. To be successful, the start of the institution would have to be driven by the business community, much as U. T. Dallas was when it began in the early 1960s. The programs offered would have to provide for the workforce needs that are not currently being met, and industry would have to be on board for supporting its development.

Another possibility for Houston is to create an Oil and Gas Institute and study opportunities in biomedical engineering that would partner closely with industry to connect U.T. System institutions and their students and faculty with needs and opportunities in the Houston area.

Additional data is needed in several areas to better quantify the need for a U.T. System presence in Houston. The broad areas for additional data focused on:

- The projected five-year and 10-year industry need for engineers in the greater metropolitan Houston area.
- The current capacity of universities in the greater metropolitan Houston area to meet these needs.
- Potential number of students who would study engineering in Houston if a U.T. System presence was established in Houston, and the potential impact on other U.T. System institutions.
- Potential support for an expanded presence of the U.T. System institutions in Houston from the local business community.
- The capacity of other U.T. institutions to provide for the workforce needs in Houston that are not being met, without a direct presence in Houston.
- The role of engineering and medicine expanding opportunities for students across the U.T. System at the Texas Medical Center in Houston.

7. The near-term challenges may call for a different approach to meeting workforce needs.



In terms of rapid response, it seems clear that the U.T. System must be open to reconsidering the required body of knowledge for certain job requirements, what curriculum is required, and what incentives might motivate students to complete an engineering degree. An initial suggestion was to consider offering all of the engineering tracks at each of the U.T. institutions in the form of a minor or certificate. Petroleum engineering was seen as a crucial specialty that may need to be rolled out at all of the institutions in the near future. The U.T. El Paso campus is a potential model that offers a general engineering undergraduate degree that can be specialized later in a student's academic path. And since engineers are not just technically-focused any more—they also need skills in business, communication, and arts to be successful—System institutions may wish to adopt a more holistic approach to engineering by reviewing curriculum requirements and building in more flexibility with course selection.

It may be, given the urgent demand for engineers and computer scientists, that the best way to meet the need in a rapid way is to "retrain" those with closely-related degrees. Much of the Task Force's discussion focused on traditional university-grounded degree programs, but there is clearly a broader need for "just-in-time education" or "continuing education" or "retraining" that falls outside the usual higher educational framework. The petroleum business is one that is especially characterized by intense development activity that places high demand on available workers immediately. These concepts were touched upon by the Task Force but need further work to fully vet.

More findings on alternate degree types can be found in **Appendix B.**

8. There is an opportunity for the U. T. System institutions to be leaders in developing regional innovation hubs.

Governor Perry recently brought leaders together to discuss the priority of evolving central Texas into an innovation hub in terms of creative invention, research facilities, and entrepreneurship. The ingredients for success seem to be in place, led by U. T. Austin and its Cockrell School of Engineering in conjunction with the College of Engineering at Texas A&M. A goal is for students to have the intellectual capital to start up new companies, since graduates coming out of research labs are in a strong position to start businesses. Public/private partnerships can leverage under-utilized land and resources, as well as bring in key tenants. Finding companies with a strong research and development (R&D) component who want to be close to schools can create opportunities for start-ups in terms of venture capital and talent management. An important step may be incorporating with the business school on each campus to create joint programs that encourage commercialization and focus on ties that students and faculty have with investors. Although these types of programs are already well developed at U. T. Austin, they may not be so well developed regionally. It was noted that Texas State University offers good programs with an emphasis on commercialization, and produces Ph.D. holders with advanced technical knowledge and business know-how, who are able to successfully build partnerships with industry.

Central Texas may not be the only region of Texas with great opportunities for U. T. System institutions to serve as innovation drivers. Texas is a business-friendly state without excessive regulation or state income tax, even though its venture capital is traditionally lower. The Dallas-Fort Worth area is a logical center with great wireless, telecommunications, and microelectronics industries, and the Dallas-Fort Worth Metroplex has been active in discussing ways to advance innovation collaboratively across institutions. As another example, advanced manufacturing represents a large opportunity in the Valley. Cyber security is an area of emphasis in San Antonio. Health care is an enormous industry, and Texas is one of the leading states in academic medicine with major research institutions in Houston, Dallas, and San Antonio. U. T. System schools of engineering have opportunities to partner with health science centers to strengthen industry's supporting medicine and health care. The energy business across the state is large and multi-disciplinary, along with manufacturing, which presents opportunities through additive manufacturing and nanomanufacturing.

9. Oil and gas producing lands are extraordinarily important to the U. T. System, its Permanent University Fund, and its Available University Fund.

There has been little engagement of the U. T. System research community in studying ways to optimize production and value from University Lands, the proceeds of which enhance the value of the Permanent University Fund, which is an extraordinarily valuable asset for the U. T. System and its institutions. The Task Force believes that there may be significant ways for the U. T. System students and faculty to engage in advanced research that could yield billions of dollars of added value to the U. T. System from these oil-producing lands, as well as provide important internship and learning opportunities to U. T. students. Proximity of U. T. Permian Basin with these lands provides a valuable U. T. System presence.

Results from the application of current and future technology to University Lands suggest that the lands may have billion barrel-plus potential net to the System's cost-free royalty. While this upside is still speculative, the magnitude of this potential is so large and the scientific expertise of our faculty is so great, that these hydrocarbon-bearing formations, and our operators' technology and environmental stewardship should be the best-studied and understood formations and practices in the world.

Utilization of University Lands may include incubation and testing ground sites for implementation of U. T. System or individual or collaborative ideas to increase reserves identification, improve hydrocarbon recoveries, reduce associated costs, and/or develop alternative means for storage or transportation of energy that can be matured for use by industry. Student and faculty real-time knowledge of industry activity may serve to promote best practices by industry and learning by students.

Meeting the Need: Increasing Engineering Enrollment and Degree Production

Each year Texas exports approximately 17,000 graduating high school students to attend colleges and universities in other states, and only brings in about 6,000 from other states, resulting in a net loss of approximately 11,000 qualified students leaving Texas for other states[11]. Texas is the second worst state in the country in terms of net loss to colleges and universities in other states, exceeded only by New Jersey. The data also suggest that only about half of students who proclaim interest in engineering actually graduate with an engineering degree, perhaps due to attrition/transferring to other institutions or general retention issues. Some who do graduate leave the state after completing their degree here. Therefore, we must also consider ways to retain graduates through internship and job opportunities at the end of their degree program.

There is a clear need for a greater number of engineers in our state. The Task Force's findings indicate that although U. T. System institutions currently graduate a large number of well-qualified engineers, we should be focusing on increasing engineering enrollment and degree production, especially from the highest-quality programs. We must identify new ways to do so, in order to meet the future needs of Texas and to provide educational opportunity to Texas students. The following findings explore the issue of increasing enrollment and degree production at U. T. System institutions.

1. The U. T. System is the current leader in producing engineering and computer science graduates in Texas.

In 2011, the U. T. System institutions awarded the following degrees in engineering and computer science:

- 2,598 bachelor's degrees (or 46% of the total of 5,589 bachelor's degrees) awarded at all Texas colleges and universities, public and private.
- 1,682 master's degrees (or 44% of the total of 3,821 master's degrees) awarded at all Texas institutions.
- 364 Ph.D. degrees (or 46% of the total of 797 Ph.D. degrees) awarded.

The total number of engineering and computer science degrees produced in 2011 was 4,644. In that same year, all other non-System public universities in Texas produced a total of 4,577 engineering and computer science degrees. Thus, the U. T. System institutions are awarding slightly over half of all the engineering and computer science degrees in Texas that are awarded from public universities.

Table 2 summarizes all degree production from all Texas institutions of higher education, both public and private. The contribution of private universities to graduates in engineering and computer science is modest. The U. T. System institutions award about 45% of all degrees in engineering and computer science in Texas, including all public and private institutions.

[11]Source: The Washington Post, "Brain Drain: States that Lose the Most College Students," Jenna Johnson, posted to the Post's website Jan. 24, 2012.

As noted earlier, the Texas Workforce Commission estimates that Texas needs to add about 9,000 new engineers and computer scientists to the workforce each year to meet business needs. The total current production of degrees from Texas institutions, which is not adequate to meet the current need, is slightly over 10,000 per year. Thus, if Texas workforce needs were met entirely from increased production from Texas institutions of higher education, the output of these institutions would have to approximately double to nearly 20,000 degrees per year. The shortage is not a small one, and the reality is that Texas will need to continue to import talent to meet the need. But the best interests of Texas, and its citizens, are served by fulfilling as much of the need as possible for these needed and high-paying jobs in engineering and computer science with home-grown talent.

Table 2: Summary of Computer Science and Engineering Degrees Awarded at Texas Institutions in 2011.

Degree	The U.T. System Total	Texas Publics (Non-System) Total	Texas Private Institution Total	Total
B.S.	2,598	2,482	509	5,589
M.S.	1,682	1,767	372	3,821
Ph.D.	364	328	105	797
Total	4,644	4,577	986	10,207

Although precise data are not available, we believe that a significant fraction of these graduates, especially from U.T. Austin, are working directly or indirectly in the energy sector. This is not surprising considering the global leadership of Texas in the energy business, and the resurgence of hydrocarbon exploration and production in Texas and elsewhere in the nation.

Texas A&M recently announced plans to double its engineering enrollment to approximately 25,000 students by 2025, under the "25 by 25" initiative. Note that the U.T. System institutions currently enroll over 27,000 students in engineering and computer science, with rapidly expanding enrollment at some institutions. Such an increase by Texas A&M would be comparable to matching the entire enrollment of engineering and computer science students in all of the U.T. System institutions across the state. The Texas A&M initiative was launched in response to a need A&M saw in the state and across the nation. Part of the plan is to develop more partnerships with community colleges, including building on the current programs in place with Blinn College. Texas A&M is also developing partnerships with K-12 schools to better ensure that students who come in are prepared to succeed.

The Texas A&M growth plan is not enough to meet the need and may not actually occur to the extent envisioned. Recall that the Texas Workforce Commission estimates that an additional 9,000 engineers and computer scientists are needed each year. If a student requires four to five years to graduate, even with a graduation rate of 80%, enrollment would need to increase by 51,000 students. The Texas A&M plan and the plan recommended later in this report, collectively, would not be too much but, rather, in combination, may come close to meeting the need. The Texas A&M plan and an aggressive U.T. System plan are needed if the challenge of adding more engineers and computer scientists to the Texas workforce is to be met.

2. Within the U. T. System, U. T. Austin is the largest and most selective institution.

Within the U. T. System, U. T. Austin receives the highest number of applicants to its engineering school and produces nearly half (46.5%) of baccalaureate degrees in engineering and computer science, although this fraction is expected to gradually decrease as other institutions expand more rapidly.

Undergraduate engineering and computer science enrollment is heavily concentrated in several schools within the System, specifically: The University of Texas at Austin (35% of the total), The University of Texas at Arlington (15%), The University of Texas at Dallas (14%), The University of Texas at San Antonio (13%), and The University of Texas at El Paso (12%). These five System institutions enroll 89% of all engineering students in the U. T. System. Likewise, three System institutions account for three-quarters of master's degrees awarded annually: U. T. Austin (31%), U. T. Arlington (26%), and U. T. Dallas (21%). However, new or expanding programs within the System may have a significant impact on these figures in the future. U. T. Austin is one of the largest producers of engineering Ph.Ds. in the United States. Within the System, U. T. Austin is the dominant producer of Ph.D. degrees in engineering and computer science, awarding 59% of the total.

3. Many well-qualified potential engineering students are not admitted to U. T. Austin because of the school's high demand and limited capacity.

Student demand and selectivity vary considerably across System institutions. Overall U. T. Austin has the highest demand (9,393 applications from potential first-time-in-college [FTIC] freshmen in 2012) and the most selectivity (2,449, or 26% of applicants, admitted). Approximately 4,000 transfer students apply annually for admission to undergraduate engineering and computer science programs at U. T. System institutions and more than half of them are admitted.

Approximately 80 to 90% of all applicants turned down for admission to an engineering college at the System institutions are turned away from U.T. Austin. Many of these students leave the state and are admitted at other highly-ranked institutions. Some of the students denied admission to the U. T. Austin engineering programs are admitted to and attend U. T. Austin in other degree fields. For some students, it appears that attending U. T. Austin is of greater importance than the opportunity to study engineering or computer science even though these engineering or computer science fields were their first choice of study.

To meet the demand for enrollment in engineering at U. T. Austin, the university plans to increase enrollment substantially. The best way to address the overall demand in Texas for additional engineering graduates is to increase the attractive alternatives at U. T. System institutions for high-quality engineering education.

At present, no information is shared among U. T. System institutions regarding applicants to engineering or computer science programs. It may be desirable to do so, with permission of the applicant, particularly for capacity-limited engineering programs. Sharing information would enable engineering programs at other U. T. System institutions to reach out to and recruit qualified applicants who are not admitted to their institution of first choice. This may be as simple as creating an additional checkbox on applications, depending on federal and privacy laws. One might consider an application process similar to the Texas Joint Medical Application Process where students match to U. T. medical schools across the state.

4. It is possible for the U. T. System to significantly increase its production of high-quality engineers across all of its institutions.

Each institution within the System was asked to describe the level of growth in enrollment and degree production that is possible at their campus over a 10-year period. The current and projected enrollments and annual degree production are discussed in detail in Appendix C, which includes a brief summary of each institution's growth plan as well as a summary of strategies to improve productivity through increased retention and graduation rates. The enrollment data, both current and projected, are tabulated in Table 3 and summarized as follows.

Table 3: Summary of Current and Potential Enrollment and Degree Production Increases.

Degree	Enrollment (2011)	Enrollment (2023)	Enrollment Difference	Degrees (2011)	Degrees (2023)	Degrees Difference
B.S.	20,097	31,626	11,529 (+57%)	2,598	3,870	1,272 (+49%)
M.S.	4,110	7,007	2,897 (+70%)	1,682	2,623	941 (+56%)
Ph.D.	3,075	5,070	1,995 (+65%)	364	591	227 (+62%)
TOTAL	27,282	43,703	16,421 (+60%)	4,644	7,084	2,440 (+52%)

U. T. System institutions are already expanding enrollment and degree production. In addition, each institution is improving retention and graduation rates, and improvements in productivity are expected to continue. U. T. System institutions are expected to continue to graduate an ever-increasing percentage of enrolled students, and typically graduate baccalaureate students in a shorter period of time.

Each U. T. System institution is unique, and plans for increasing enrollment and degree production are also unique. U. T. Austin is planning a significant increase in Ph.D. production that will bring its profile into better alignment with the most highly-ranked engineering programs. The emerging research universities (U. T. Arlington, U. T. Dallas, U. T. El Paso, and U. T. San Antonio) are planning for significantly increased Ph.D. production to bring their institutional profiles into closer alignment with nationally competitive research universities. Texas has just three top-level academic research universities as measured by membership in the Association of American Universities (AAU), compared to nine for California and six for New York.

A brief summary of institutional needs to support expansion is as follows:

- U.T. Arlington plans to increase engineering training include both on-campus and online expansion of the engineering programs, requiring additional faculty and space.
- U.T. Austin requires construction of its proposed new engineering building and enhanced recruitment of research-active as well as teaching faculty with professional qualifications.
- For U.T. Brownsville, the key areas are substantially increasing the enrollment and graduation rate in the engineering and computer science programs. Also, building the infrastructure to meet the sustained growth in these programs.
- U.T. Dallas needs significant new buildings and associated space, as well as start-up funds.
- For U.T. El Paso, in additional to more space, the biggest hurdle in becoming a top-tier research university is change in culture emphasizing research as part of the University's mission.
- For U.T. Pan American, the key areas are enhancing the K-12 student pipeline and the existing space infrastructure with the ultimate goals of making the College a first choice for students in the region, strengthening the graduate programs and developing a doctoral program in engineering.
- U.T. Permian Basin needs to grow existing programs and add an additional engineering building.
- U.T. San Antonio does not plan to increase significantly the size of the university but does plan to substantially increase the size of its engineering school, creating pressure for more space and additional faculty.
- U.T. Tyler is embarking on a bold experiment by offering degree programs in Houston, where growth opportunity is very large.

We are in the process of creating a new university that will result from the consolidation of U.T. Brownsville and U.T. Pan American and will include a medical school. This will result in a new university with innovative and cutting-edge academic programs that will transform the Rio Grande Valley. The new university presents a unique and exciting opportunity regarding the fields of engineering and computer science. The existing activities related to advanced manufacturing together with the engineering and computer science synergies, resulting from the establishment of a South Texas medical school, will transform the region, creating a strengthened innovation ecosystem in the Rio Grande Valley. The need for engineers and computer scientists in the Valley remains strong and will continue to increase. The creation of the new university will result in innovative, interdisciplinary, and collaborative programs in engineering and computer science directed at meeting the educational and economic needs of South Texas and beyond.

Overall the primary commitment needed to realize this growth potential would be new buildings, an increase in faculty numbers, and support of online programs. In the interim, working with the current pool of engineering majors and getting more of them to graduate from their programs in the shortest time frame possible would also be beneficial. Increasing retention and graduation efforts is not only good for the institutions; it will also pay off with an increased number of qualified candidates for the workforce.

It is not, however, enough to increase the quantity of engineering graduates; it is essential that U.T. System graduates attract high-quality employment opportunities and are equipped to go on to build successful careers. This will require constant innovation and collaboration with industry so that more top employers recruit across the U.T. System.

The charge to the Task Force was to examine needs over the next 25 years. In terms of specific planning, a time frame of roughly 10 years was thought to be the optimum one – long enough practically to have realistic hope of implementing growth but not so long as to bring into question the underlying assumptions. There is no reason to expect that the demand for engineers will do anything but continue to expand after 10 years. The strategies outlined here, though articulated and quantified over a 10-year time frame, are thought of in the context of a 25-year strategy.

5. Opportunities exist to share resources and strengthen collaboration among U. T. System colleges of engineering, leveraging assets of the Institute for Transformational Learning.

Better collaboration across the U.T. System engineering schools could lead to improved efficiencies, increased enrollment, and higher graduation rates. New degrees, and perhaps even types of degrees, may offer students more specialized, career-focused options. While there are no particular barriers to collaborative efforts among institutions, it is clear that there is the opportunity to do more. Perhaps because each institution is fully occupied managing its own situation and opportunities, limited efforts have been made so far to pursue broader, collaborative opportunities with potential for overall benefit to the U.T. System.

One way to strengthen resource sharing is to explore the use of technology in Systemwide ways to improve recruitment, program delivery, and retention across the state. The Institute of Transformational Learning may be a good resource to help the colleges use technology as a means of sharing or teaching best practices. It was also noted that technology may be useful in finding new ways to deliver current course material to additional campuses within the System.

The U.T. System institutions do not at present have any formal program established that allows students to study or conduct research at another U.T. System institution for a brief period (e.g., a semester). Exchange programs are desirable to provide a student with an opportunity to broaden their horizons or to tap into research or educational resources not available at the student's home institution. Exchange programs exist among some universities outside Texas. For example, the Committee on Institutional Cooperation (CIC) consists of Big Ten institutions plus several others (The University of Chicago, The University of Maryland, and Rutgers University). Since 1963 the CIC has had a Traveling Scholars Program that allows doctoral students to spend up to a full academic year at another CIC institution with no change in the registration procedures at their home university and no change in tuition. The U.T. System might consider a program that permits exchange of students at either the baccalaureate or graduate degree level, although capacity limitations at some institutions, such as U.T. Austin, may restrict availability to students during peak times.

The CIC also offers CourseShare, which allows a student to take an online course from any CIC member institution and have the grade recorded on the student's home institution transcript. With online courses offerings expanding at the U.T. System institutions, opportunities abound to expand the courses available to students by implementing a similar program.

Other opportunities exist to promote inter-institutional collaboration, including:

- Funding collaborative research or teaching pilot projects that require inter-institutional (academic-academic or academic-health) collaboration and that are expected to result in larger and more significant collaborative efforts.
- Sharing career center information, allowing, for example, a company to recruit from all U.T. System institutions from a single access point – this might prove particularly valuable for students at institutions that are not as well known by certain companies and open doors for new opportunities for both businesses and students.
- Systemwide collaborative institutes that bring together resources for those who need U.T. System institution talents, such as an Oil and Gas Institute or an institute focused on engineering for medicine.
- Coordinated strategic development of and participation in massive open online courses (MOOCs), perhaps offering special programs for alumni or industrial supporters.
- Annual meetings of the U.T. System institution engineering deans, perhaps accompanied by the chairs of their industrial advisory groups, to plan and coordinate.

Pipeline Challenges

Fundamental challenges exist when it comes to increasing the engineering pipeline for U.T. System institutions—specifically in terms of how to attract and retain more academically-qualified students to engineering, how to improve math and physics readiness, and how to foster additional interest in the field. In addition to increasing capacity within the System, it is crucial to continue developing a pipeline of strong, qualified, and interested candidates for the engineering field. Enrollment and degree production cannot be increased without an adequate pipeline of interested and qualified students. The following areas were identified by the Task Force as challenges for creating a robust pipeline.

1. In the United States, there are not enough students pursuing careers in science, technology, engineering, and math (STEM) fields—and the gap is being filled by foreign students graduating from American colleges and universities.

The current pipeline is not big enough, and there are not enough qualified engineering students to match the industry's needs. Thus, an emphasis on preparing interested students and retaining them through graduation is of great importance. Inadequate knowledge of mathematics leaves too few Texas high school students well prepared to pursue degrees in engineering, and most are not able to handle calculus in college. Only 2.6% of Texas high school students score a three or higher on their Advanced Placement (AP) Calculus exam, which is below the national average and significantly below the average in California[12].

Many incoming students also lack physics preparedness, or do not have a good understanding of how math and physics work together. This is an opportunity where the U.T. System may have some control over improving comprehension earlier in the process. Task Force members noted that teacher preparation may contribute to this and that better training for state middle and high school teachers may be a viable solution, specifically if energy was focused on key feeder high schools in the beginning.

Raising the attractiveness of engineering and computer science to underrepresented and minority groups in the United States also remains a major challenge. Gender issues continue to be present—while interest among male high school graduates in engineering increased slightly from 1999 to 2004, from 16.5% to 17.9%, female interest remained flat at 2.9%, despite efforts nationwide to attract more women to the field. A strategic, coordinated approach is advisable for increasing the participation of underrepresented minorities and women in engineering and computer science programs in the U.T. System.

This market gap is being filled by international students who graduate from colleges and universities within the United States. According to Witliff[13], "Although our country's educational institutions graduate about 85,000 engineering bachelor's degrees annually, the federal government annually grants 100,000 to 150,000 foreign-born and degreed engineers and scientists permanent residency visa just to meet the demands of U.S. industry."

Many (perhaps most) people do not understand what engineers do or grasp the importance of the field, particularly as the role of an engineer has evolved over the years. Even students who are math-ready often do not understand what courses are involved in engineering and what career opportunities are available after graduation. Essentially all state and national engineering organizations have been aware of this issue for years, and have put money and time into programs that promote engineering in the schools—supporting the notion that this is not just a U.T. issue, but a larger society issue. Many school teachers do not seem to encourage engineering as a field because they do not know enough to explain it well to students. Some also do not seem to know that the U.T. System offers engineering programs outside of the Austin campus.

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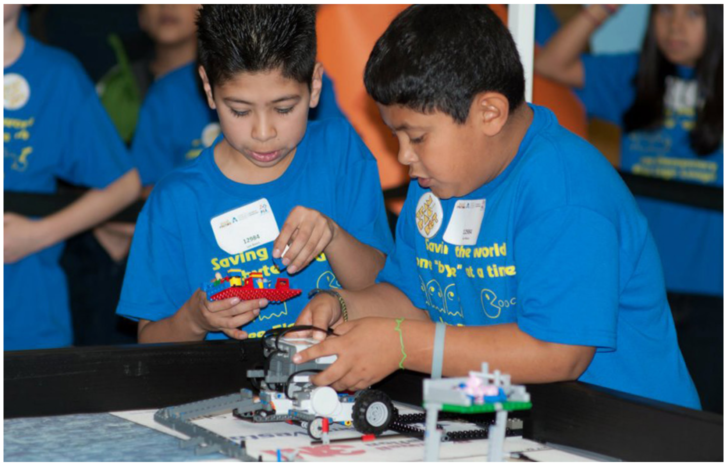
[12]Source: U.T. System, Market Share Supply analysis, Graph 2.

[13]Source: Witliff, D. "Growing More Engineers: Critical to Our Nation's Future," PE –The Magazine for Professional Engineers, March 2013, p. 33.

Creating new educational or marketing materials for teachers and school staff that outline specific career paths, starting salaries, and college coursework may be an idea worth pursuing further, especially if it can demonstrate how exciting the profession can be and how it is not innately "hard" but instead rewarding hard work for those who have the drive and passion to pursue it. There may be a way to collaborate or build on the UTeach program, as well as consider offering a pilot high school-level engineering class to provide students with an opportunity to see practical applications of engineering and better understand what the major and field entail. The Cockrell School of Engineering at U. T. Austin participates in the institution's UTeach program, providing those who earn engineering degrees the opportunity to become secondary school teachers and bring real engineering knowledge and inspiration into our schools. Expansion to other U. T. System colleges of engineering warrants careful consideration and, potentially, start-up funding support. There is also a strong need to attract STEM graduates into the K-12 teaching profession, for which supporting alternative credentialing programs such as the Relay Graduate School of Education may be valuable.

There is significant opportunity for the Institute for Transformational Learning to play an important role in motivating and preparing students to attend engineering schools in the U. T. System. Online tools that reach broadly across the state and tap the U. T. System institution resources could prove very effective.

2. The changing demographics in Texas make it imperative to reach out to the rapidly growing population of Hispanic students and attract them, along with more women, to careers in engineering and computer science.



At present, only about 20% of engineering students nationwide are female. One of the best ways to address the pipeline issue is to attract more women to careers in engineering and computer science. Online tools and other strategies may help. Nationwide, numerous programs in professional and technical societies exist to encourage women to pursue careers in science and engineering. There is not much indication that these programs are having much effect on the overall enrollment of women in engineering or computer science programs.

The rapidly growing population of Hispanic students is well recognized in Texas. Any attempt to improve the pipeline of students to engineering and computer science fields must address this growing segment of our population.

Because many segments of Texas' growing population of K-12 students are economically disadvantaged, strategies to build the pipeline should address affordability and access for those students. There would be little point in encouraging and preparing students to go to college and study engineering or computer science if well-qualified students could not afford to attend college.

Recommendations

Recommendations

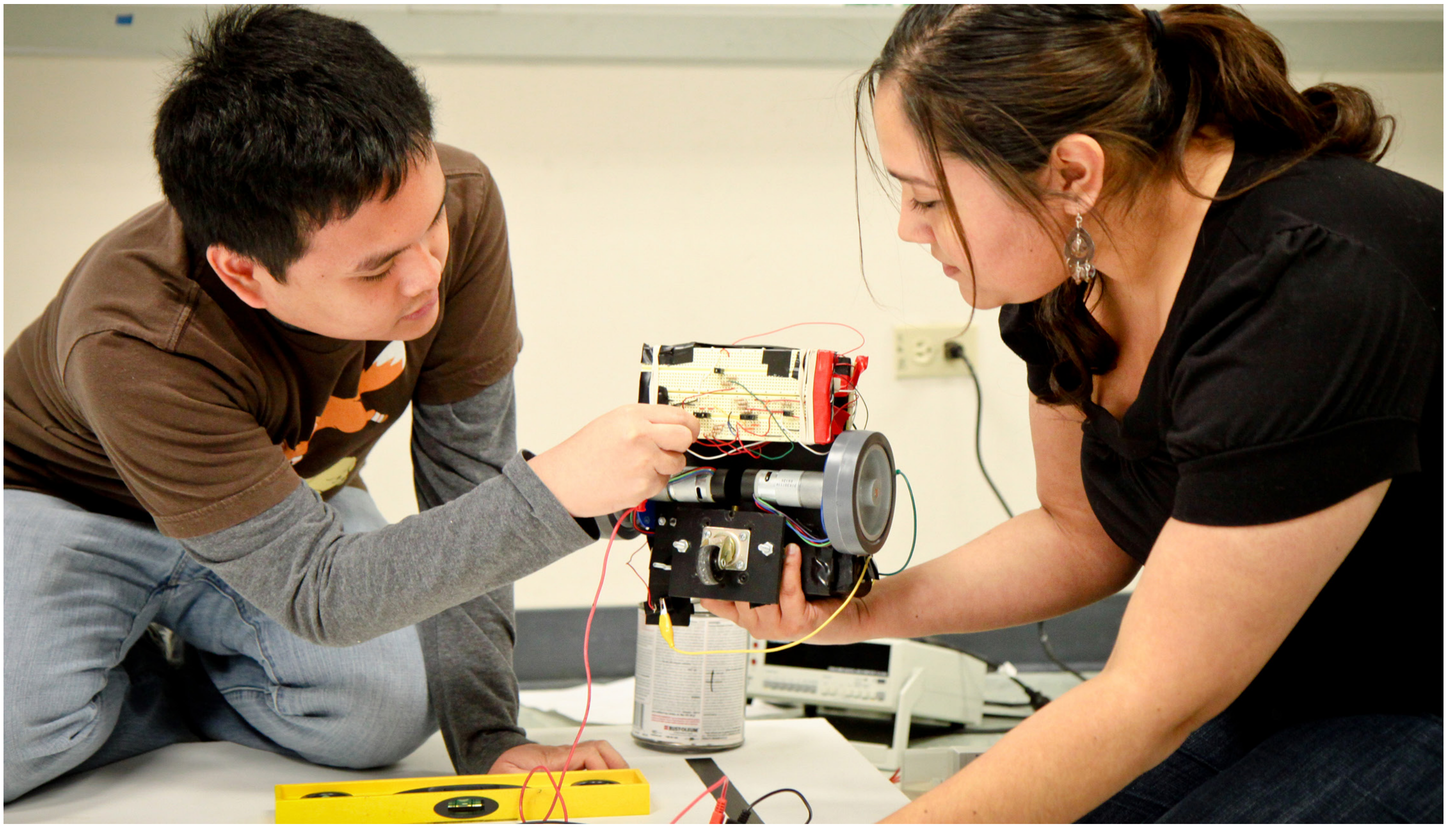
The market is loudly and clearly indicating that there is a shortage of high-quality engineers and is calling on institutes of higher education to react and expand the supply. The Engineering Task Force presents five recommendations aimed at addressing this conclusion, specifically to: (1) expand production of engineers in Texas, (2) encourage more young Texans to pursue careers in engineering and other STEM fields, (3) encourage stronger interactions with industry, (4) use the U. T. System faculty and students, in conjunction with industry, to gain more value from oil and gas production on University lands, and (5) brand the initiative.

Recommendation 1: Expand Production of Engineers in Texas

The U. T. System should develop a strategic plan to expand engineering enrollment and degree production across the U. T. System, more or less in accord with Table 3 and Appendix C.

A successful plan will clearly define the specific actions and investments needed to realize the planned expansion (e.g., new buildings, increase in number of faculty, online programs, exchanges of students among campuses, collaborative classes, changes in policies, etc.), and planning the distribution of these investments over a 10-year period. This strategic plan will also need to establish benchmarks, performance metrics, and contingency plans consistent with the Chancellor's Framework for Excellence. Institutions should be required to meet specific milestones along the way with go/no-go decision points for various critical elements.

It is important to implement this recommendation for two reasons: (1) Texas cannot afford to be reliant on other states or nations to supply the critical human resources that it will need to sustain prosperity – Texas must control its own destiny; and (2) the career and earning opportunities for Texans in the fields of engineering and computer science are enormous, and failure to provide Texas students with opportunities in these fields would be an abrogation of responsibility.



Recommendation 2: Encourage More Texans to Pursue Engineering Careers

The U.T. System should be a leading national force in building a strong STEM pipeline so that the state will have the scientific and engineering talent needed to compete and prosper.

The essential elements to consider include:

- **Qualified teachers.** The UTeach and UTeachEngineering programs developed by U.T. Austin are models of success and should become the cornerstone of the U.T. System as it contributes critical teaching resources to the state. More output from UTeach-type programs would be of great benefit to Texas, as would support of graduate education and alternative licensure programs, which could attract STEM graduates to pursue K-12 teaching careers.
- **Summer programs in partnership with industry.** Many students in various parts of our state do not have opportunities to engage in learning opportunities related to engineering. Perhaps the only way to take such programs to scale is through the Internet. The U.T. System should utilize the Institute for Transformational Learning, and initiatives from faculty at U.T. System institutions, to explore ways to reach more young Texans and, for those with an interest in engineering or other STEM fields, provide opportunities for learning and motivation.
- **Focusing on proven programs.** While there is already much activity in terms of STEM outreach, according to a recent statement from the White House, this activity has not been effective at meeting our nation's requirements. There is a need to more clearly define and focus on those activities that are effective. U.T. System institutions should coordinate STEM teaching and outreach efforts with other existing efforts, such as those at the National Science Foundation, to ensure that activities concentrate on those that have been shown to be effective.
- **Attacking the math problem.** The key barrier that impedes students from being qualified to pursue engineering careers is lack of proficiency in math, especially higher levels of math. The issue of preparedness arises at all levels: in K-12 education, in community college education, in freshman math, and in science education. Studies show that most potentially-oriented STEM students that are lost lose interest in middle school when they are first introduced to algebra and geometry. The goals for growth outlined herein cannot be met unless this K-12 pipeline problem is ameliorated. The U.T. System and its institutions should review best practices and determine what it can best do to help Texas.
- **Opportunities with community colleges.** The pathway from community college to four-year institution is becoming increasingly important, especially in light of ensuring access and affordability for students. All U.T. System institutions have established valued relationships with regional community colleges, yet this pathway to engineering and computer science degrees is underutilized and could be strengthened. Several U.T. System institutions have best practices that could be borrowed from by others. The U.T. Tyler program in Houston will provide an especially important experience base in terms of expansion away from the region of the home university and should be both nurtured and examined carefully for lessons learned.
- **Increasing the prestige of engineering.** While not specific to Texas, the lack of understanding of the rewards of a career in engineering is one of the major barriers to increasing the number of qualified engineers. The U.T. System could encourage engineering faculty and alumni to lobby their professional organizations (i.e., TSPE, SWE, CEC, etc.) and technical societies (i.e., IEEE, AICHE, ASME, etc.) to make more high school students aware of the high value and lifetime earnings of engineering graduates.
- **Attacking the diversity problem.** Unless the problem of too few women and underrepresented minorities in engineering and computer science is effectively addressed, particularly with changing demographics in Texas, progress toward building the pipeline will likely be limited. The Task Force recommends that the U.T. System collect and report data, identify programs or practices that seem to be working well, and support innovative initiatives across the System and at high schools to support increased and improved STEM pipeline especially among underrepresented groups.

Recommendation 3: Encourage Stronger Interactions with Industry

The U.T. System should review opportunities for and barriers to expanded industry engagement, with the goal of promoting greater support for the U.T. System engineering programs and better return on investment for industry.

This effort should include as a minimum the following elements:

- **Intellectual property.** Modification of the U.T. System Intellectual Property (IP) rules for academic institutions to encourage far greater industry support of research. Serious consideration should be given to making the default IP position for industry-sponsored research be a non-exclusive, royalty-free license (NERFL).
- **Regional innovation hubs.** Assessment of opportunities to partner with others in Regional Innovation Centers, e.g., Central Texas, and development of plans in collaboration with elected officials to launch significant new initiatives aimed at enhancing economic development.
- **Internship and Co-Op programs.** Encourage U.T. System programs for internships, co-op opportunities, and career opportunities. Although some institutions have highly-effective career centers, much of the planned growth is going to occur at institutions that currently have new or small engineering programs. Developing more opportunities to practice engineering while pursuing an undergraduate engineering degree provides benefits for all students. The U.T. System brand and tools, such as websites (perhaps partnered with MyEdu), could provide value to students and businesses.
- **Houston.** A plan should be developed for building a strong presence in Houston, and include at minimum a consideration for expansion of the U.T. Tyler program in Houston and creation of an Oil and Gas Institute to partner with industry in Houston for research and educational purposes and to house other educational programs designed to serve the Houston community. The plan should also consider working with Health Affairs and Academic Affairs to consider the role of medicine and engineering at the Texas Medical Center.
- **Oil and Gas Institute.** Texas is a powerful force, renowned worldwide, in hydrocarbon energy research, exploration, production, and refinement. The U.T. System should consider forming a multidisciplinary Oil and Gas Institute to link faculty and student interests with industry needs.
- **Industry-sponsored research.** U.T. System institutions should review their incentives and establish stretch goals of perhaps 25% of research expenditures from industry. Concepts such as preferred status for major sponsors or alumni may prove useful in some cases, along with hiring more faculty with experience conducting research for industry and better informing research faculty on how best to engage industry in research.
- **Faculty with ties to industry.** The U.T. System institutions should enhance their ranks of suitably-credentialed, professionally-qualified faculty (but not necessarily with Ph.D.) with deep roots in industry to support greater collaboration and to attract stronger research support from industry, as well as assure that curricula and instruction are in tune with industry needs. Programs such as those in which industry loans engineers and computer scientists to a university may help to address this issue and build stronger relationships.
- **Position industry representatives within dean's leadership teams.** The U.T. System institutions should ensure that industry advisors are engaged in a real and meaningful way and brought inside the dean's leadership team. Strategies for accomplishing this are many, but one that has worked well at some institutions is to have an Associate Dean with a very strong industry background to bring the industry perspective to the decision making process.
- **Encourage professional licensure.** Texas needs more engineers, and Texas needs more licensed professional engineers. By encouraging licensure, U.T. System institutions can help to build stronger relationships with industry.

Recommendation 4: Gain More Value from University Lands

The U. T. System should launch an initiative to fund research at U. T. System institutions, possibly in collaboration with industry, on ways to maximize value and revenues from oil and gas production on University Lands.

While necessarily local in initial scope, this effort should be built as a significant and globally useful multidisciplinary effort to enhance production while also bringing innovation to the related environmental and surface issues.

Recommendation 5: Develop an Overall Branding Initiative

The U. T. System should consider branding this initiative in a way that helps to knit together the various elements into a comprehensive strategy, and that ensures national awareness and visibility, which will benefit U. T. System institutions, students attending U. T. System institutions, Texas businesses, and the state as a whole.

The Task Force believes that initiating a branding exercise to bring together the various elements of the recommended program, and developing a simple, powerful slogan for this initiative, would be beneficial. The Task Force does not recommend hype but, instead, believes that grounding any branding initiative to the real work and impact of computer scientists and engineers on the Texas economy should be the basis for going forward. A plan needs to be developed to communicate the key elements of any program that is implemented with newspapers, chambers of commerce, and other outlets and organizations.

Cost of Implementing the Plan

Engineering programs are not inexpensive, and an initiative to expand enrollment has a price tag associated with it. Quantifying the funding requirements and availability of funds over time will be a critical next step.

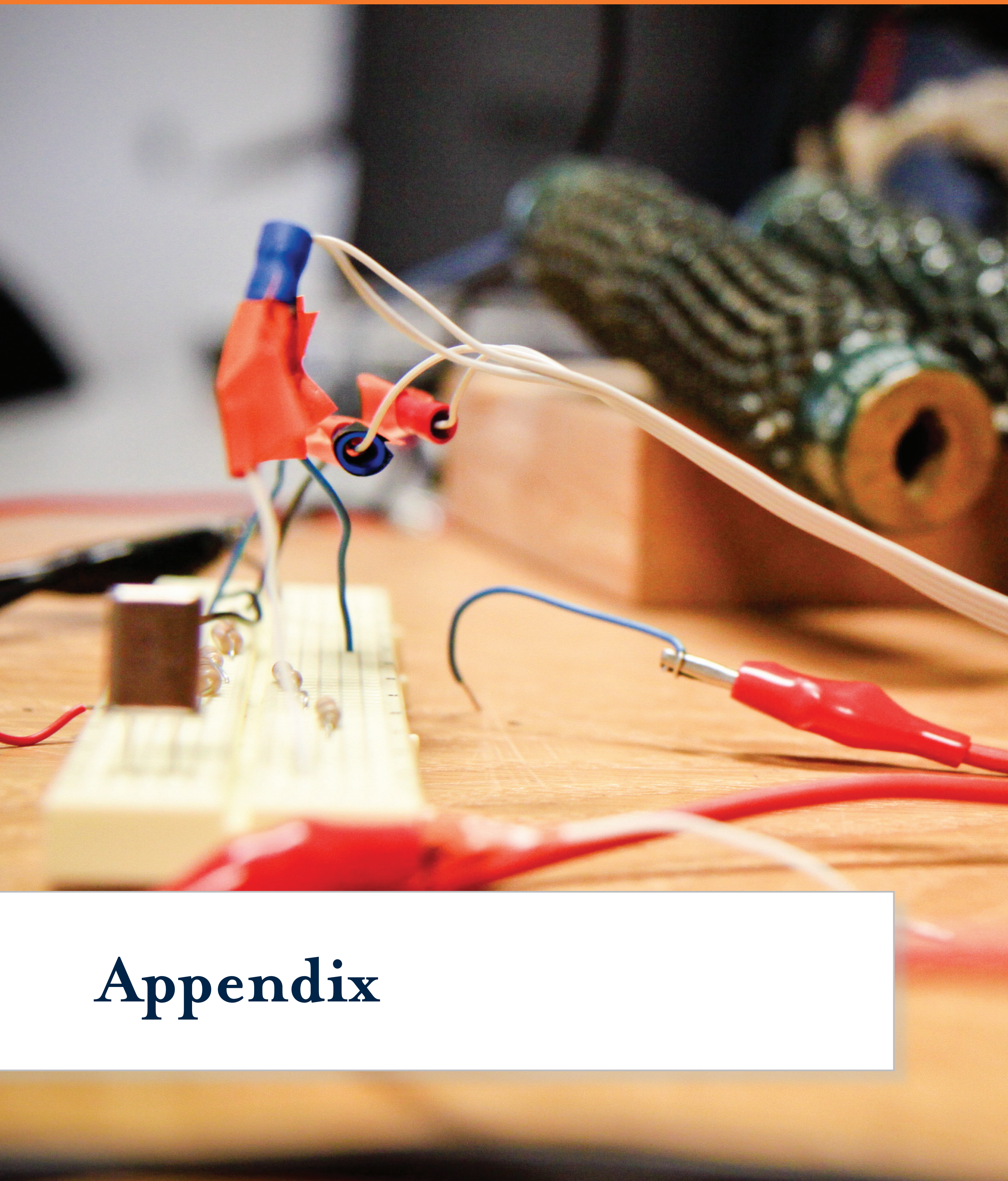
Appendix D discusses the potential range in cost by extrapolating from current circumstances but also noting areas with potential for reducing these projected costs. The pilot program by U. T. Tyler in Houston is an example of a program that may have high output at relatively low cost. By utilizing the resources of the Institute for Transformational Learning, there may be opportunities to offer online courses across multiple institutions that will achieve economies of scale. Space is a major component of cost – more efficient use of space may help to contain the cost of added student enrollment and degree production. By engaging more significantly with industry, significant new resources may be secured to help meet the funding needs. In any case, engineering education tends to be laboratory intensive, and engineering faculty at most System institutions are research-active, which requires significant investments in laboratories and equipment. The growth initiative at U. T. Austin suggests that educational quality need not be compromised and may even be enhanced by undergraduate growth that is partly supported by the hiring of faculty who are focused on teaching and who possess strong professional credentials.

Countering these costs is the enormous return on investment for students (whose lifetime earnings will typically soar in the engineering field) and for Texas as a whole. The recommended initiative, if implemented successfully, would represent the most significant investment in engineering education in the United States in recent times. As such, it would tend to attract even more qualified people and businesses to Texas.

Next Steps

If the U. T. System Board of Regents believes that the recommendations presented by the Engineering Task Force warrant serious consideration for implementation, the following follow-up steps are recommended:

- **Develop detailed plans from each campus.** Request detailed plans from each campus to increase enrollment and degree production in computer science and engineering, engaging industry advisory boards and local companies/stakeholders in a deep way in the planning process. The plans should cover a 10-year period, should be designed to be self-supported at steady state, and should identify any essential resources needed to accomplish the plan and describe any specific ideas for creative financing, for instance, via industry support.
- **Online instruction.** The Institute for Transformational Learning should be tasked with working closely with U. T. System institutions to develop specific plans for online instruction that would meet the institution's needs, be consistent with plans for enrollment growth, and address objectives such as building the K-12 pipeline for engineering.
- **Houston.** A plan should be developed for building a strong presence in Houston, and include at minimum a consideration for expansion of U. T. Tyler's program in Houston and creation of an Oil and Gas Institute to partner with industry in Houston for research and educational purposes and to house other educational programs designed to serve the Houston community.
- **Funding requirements.** Once detailed plans are developed by each campus and strategies for online instruction and developing greater engineering capability in Houston crystalize, the funding requirements over time need to be identified.
- **University Lands.** The U. T. System should develop a plan to conduct research that will maximize the return on its state lands and, hence, maximize the value of the Permanent University Fund.



Appendix

Appendix A: Task Force Committee Bios

Regent Alex M. Cranberg (Houston, TX)

Task Force Co-Chair and Regent, The University of Texas System Board of Regents
Alex Cranberg was appointed to a six-year term on The University of Texas System Board of Regents by Governor Rick Perry in February 2011. Regent Cranberg serves as a member of the Audit, Compliance, and Management Review Committee; Facilities Planning and Construction Committee; Finance and Planning Committee; and Technology Transfer and Research Committee.

Mr. Cranberg is Chairman of Aspect Holdings, LLC. He graduated summa cum laude from The University of Texas at Austin in 1977 with a B.S. in Petroleum Engineering and received an M.B.A. from Stanford University in 1981.

Dr. David E. Daniel, PE (Dallas, TX)

Task Force Co-Chair and President, The University of Texas at Dallas
Dr. David E. Daniel is the fourth president of The University of Texas at Dallas. He received his bachelor's, master's, and Ph.D. degrees in engineering from The University of Texas at Austin, and served on the faculty at U.T. Austin from 1980 to 1996. In 1996, he moved to the University of Illinois, finishing his service as Dean of Engineering before being appointed president of U.T. Dallas in 2005.

Dr. Daniel's professional work has been recognized by the American Society of Civil Engineers, which awarded him its highest honor for papers published in its journals (the Norman Medal), and on two separate occasions awarded him its second-highest honor, the Croes Medal. He received the Presidents' Award in 2007 and the OPAL (Outstanding Projects and Leaders) Award for Education for 2010. In 2000, he was elected to the National Academy of Engineering, the nation's most prestigious organization recognizing engineering achievement.

Dr. C. Mauli Agrawal, PE (San Antonio, TX)

Dean, College of Engineering, The University of Texas at San Antonio

Dr. Mauli Agrawal specializes in the area of orthopedic and cardiovascular biomaterials. His work in these fields has resulted in several patents, many of which have been licensed to commercial entities. His lab is currently investigating tissue engineering approaches to treat aortic aneurysms, developing new technologies for drug eluting stents, exploring some revolutionary techniques for preventing blood loss related to battlefield injuries, and developing stent based micron-thin implantable blood pressure sensors.

Dr. Agrawal received his bachelor's degree from the Indian Institute of Technology Kanpur, his master's degree in Mechanical Engineering from Clemson University, and his Ph.D. in Materials Science from Duke University.

Dr. Khosrow Behbehani (Arlington, TX)

Dean, College of Engineering, The University of Texas at Arlington

Dr. Khosrow Behbehani, former Chair of the Bioengineering Department at The University of Texas at Arlington, was named Dean of the University's College of Engineering on May 15, 2013. In 2005, Dr. Behbehani successfully led an effort to elevate the status of the bioengineering program to the department level. In his tenure, research funding for the department has increased by 12 times and the number of tenured and tenure-track faculty has more than doubled. Student enrollment has grown by more than five times.

Most recently, Dr. Behbehani successfully led an effort to establish a new Bachelor of Science degree in Biomedical Engineering, which began offering classes last fall.

Dr. Francisco G. Cigarroa, (Austin, TX)

Chancellor, The University of Texas System, ex officio

Francisco G. Cigarroa, M.D., leads one of the nation's largest systems of higher education, with nine academic institutions and six health institutions that educate more than 213,000 students and employ 87,000 faculty and staff. Dr. Cigarroa is a nationally-renowned leader in higher education as well as a highly-respected transplant surgeon. Prior to becoming chancellor, he served as president of the UT Health Science Center in San Antonio. A native of Laredo, Dr. Cigarroa became the first Hispanic chancellor of the UT System when he was appointed by the Board of Regents in 2009. President Barack Obama appointed Dr. Cigarroa to serve as commissioner on the White House initiative on Educational Excellence for Hispanic Americans, and in October, Dr. Cigarroa received the Chair's Award, one of the highest honors by the Congressional Hispanic Caucus. As chancellor, Dr. Cigarroa has championed student access and success and made expanding educational opportunities in South Texas one of his top priorities.

Samuel G. Dawson, PE (San Antonio, TX)

Chief Executive Officer, Pape-Dawson Engineers and Chairman of The University of Texas at Austin External Engineering Advisory Board

As CEO for Pape-Dawson Engineers, Samuel Dawson is responsible for the firm's management, allocation of resources, strategic planning, and operations. He is also responsible for reviewing and coordinating major projects. Pape-Dawson Engineers is one of the largest civil and environmental engineering firms in Texas. Dawson is active as a volunteer and serves on numerous boards and committees including: Chairman of the Greater San Antonio Chamber of Commerce, the founding Chairman of the San Antonio Mobility Coalition, past Chairman of the Witte Museum Board of Trustees, President of the Rotary Club of San Antonio and Board Member of the Tobin Center for the Performing Arts.

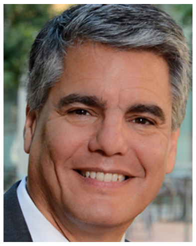
He is an active member and former President of the Texas Society of Professional Engineers, American Society of Civil Engineers, and Professional Engineers in Private Practice. Dawson currently serves as Chairman of the Engineering Advisory Board at the University of Texas and is the Advisory Council Chairman for the University of Texas at San Antonio's College of Engineering.

Dr. Immanuel Edinbarough, PE (Brownsville, TX)

Associate Dean, CSMT and Director of Engineering Technology, The University of Texas at Brownsville and Texas Southmost College

Dr. Immanuel Edinbarough joined The University of Texas at Brownsville and Texas Southmost College in 2000, where he specializes in microsystems, MEMS, nano manufacturing, artificial intelligence, mechatronics, machine vision, remote manufacturing and robotics and automation and engineering technology education. His previous experience has focused on machine tool, CNC, turbines, pump, and motor manufacture. Dr. Edinbarough earned his B.S. from the University of Madras in India, a B.E. degree from the Institution of Engineers in India, his M.S. degree from Bharathiar University in India, and his Ph.D. from Bharathiar University in India.

Dr. Gregory Fenves (Austin, TX)



Executive Vice President and Provost, The University of Texas at Austin

Prior to his appointment in October 2013 as Executive Vice President and Provost, Dr. Gregory Fenves served as the eighth dean of the Cockrell School of Engineering at U. T. Austin. With more than 7,500 students and research expenditures exceeding $160 million a year, the Cockrell School is a top-10 ranked engineering school.

During his five-year leadership of the school, Dr. Fenves recruited 57 engineering faculty, bringing the total number of tenure/tenure-track faculty to 278 faculty members. He helped increase the entrepreneurial and technology commercialization programs for students and faculty throughout U. T. Austin.

Dr. Forrest Flocker (Odessa, TX)

Associate Professor of Mechanical Engineering, Undergraduate Chair of Industrial Technology and Engineering, The University of Texas of the Permian Basin

Prior to joining the faculty at U. T. Permian Basin, Dr. Forrest Flocker was a member of the mechanical engineering faculty at Trine University in Angola, Indiana. He also worked as an engineering consultant serving the offshore oil industry in Houston and as a production and maintenance engineer for the U.S. Army Aviation and Troop Support Command in St. Louis, Missouri. Dr. Flocker holds a B.S. in Mechanical Engineering from The University of California – Davis, a master's in Engineering Mechanics from Missouri University of Science and Technology, and a Ph.D. in Engineering Mechanics from The Missouri University of Science and Technology.

Dr. Miguel A. Gonzalez (Edinburg, Texas)

Dean, College of Engineering and Computer Science, The University of Texas-Pan American

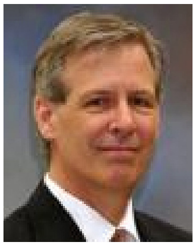
Dr. Miguel Gonzalez serves as the Dean in the College of Engineering and Computer Science at U. T. Pan American. He has a significant amount of executive industry experience where he held managerial and executive positions. His work has been funded from various sources including NASA, The National Science Foundation, The Texas Higher Education Coordinating Board's Advanced Research Program, U. S. Department of Commerce, and The U. S. Department of Labor. One of his current interests is in the area of manufacturing systems for rapid product design and development in international production. An extension of this work is the current effort that established the U. T. P. A. Rapid Response Manufacturing Center in a consortium of academic institutions, economic development corporations, industry, and local, state, and federal governments.

Jeffery D. Hildebrand (Houston, TX)

President and CEO, Hilcorp Engineering Co.

Jeffery D. Hildebrand's entrepreneurial acumen became evident when he began running his own oil and gas production company three years after completing a master's degree in Petroleum Engineering from The University of Texas at Austin. Hildebrand founded Hilcorp Energy Co. in Houston, where he serves as president and chief executive officer for the company, which has 375 employees and interests in more than 3,000 wells. The company is a major oil and gas producer, and has a venture-capital subsidiary that invests in real estate and businesses. Hildebrand was appointed to the U. T. System Board of Regents by Governorn Rick Perry in 2013.

Dr. James K. Nelson (Tyler, TX)



Dean of Engineering and Computer Science, The University of Texas at Tyler

Dr. James K. Nelson received a Bachelor of Civil Engineering degree from the University of Dayton in 1974. He received the Master of Science and Doctor of Philosophy degrees in civil engineering from the University of Houston. During his graduate study, Dr. Nelson specialized in structural engineering. He is a registered professional engineer in three states, a Chartered Engineer in the United Kingdom, and a fellow of the American Society of Civil Engineers. He is also a member of the American Society for Engineering Education and the SAFE Association. Dr. Nelson's primary research interests include evaluating the behavior and performance of lifesaving appliances for the marine and offshore industries, including development of rationale international regulations; the development of software-based tools and systems for engineering design, and expanding the engineering pipeline through programs to interest students in the fields and programs to facilitate completion of an engineering degree.

Dr. John Randall (Richardson, TX)

President, Zyvex Labs and The University of Texas at Dallas External Engineering Advisory Board

John Randall has over thirty years of experience in micro- and nanofabrication. He is a key contributor to Zyvex Labs, having defined the company's Atomically Precise Manufacturing program, where he serves as Program Manager and Principal Investigator. He originally joined Zyvex Corporation in March of 2001 after 15 years at Texas Instruments, where he worked in high resolution processing for integrated circuits, MEMS, and quantum effect devices. Prior to working at TI, John worked at MIT's Lincoln Laboratory on ion beam and x-ray lithography. Dr. Randall complete his B.S. in Electrical Engineering (cum laude) from the Honors Program at the University of Houston, then went on to receive his M.S. in Electrical Engineering from the University of Houston. He earned his Ph.D. in Electrical Engineering from the University of Houston in 1981.

Dr. Pedro Reyes (Austin, TX)

Executive Vice Chancellor for Academic Affairs, The University of Texas System, ex officio

Dr. Pedro Reyes received a bachelor's degree in American History and Education and a Ph.D. in Education Policy & Administration from The University of Wisconsin–Madison. From 1985 to 1986, Dr. Reyes served on the faculty at The University of Kansas, Lawrence, after which he returned to The University of Wisconsin–Madison as a member of its faculty, where he stayed until 1990. In 1991, Dr. Reyes joined The University of Texas at Austin, serving as a member of the faculty. Dr. Reyes was named the Associate Vice Chancellor for Academic Planning and Assessment for The University of Texas System in 2003 and was appointed Executive Vice Chancellor for Academic Affairs in 2012.

Dr. Richard Schoephoerster (El Paso, TX)

Dean, College of Engineering, The University of Texas at El Paso
Since 2007 Dr. Richard Schoephoerster has been the Dean of the College of Engineering at The University of Texas at El Paso, where he leads a college of over 80 faculty members in 24 different B.S., M.S., and Ph.D. degree programs. In his first four years at the college, the student population has grown by 25% (from 2500 to over 3000 students, including over 500 graduate students), and the annual research expenditures for the College have doubled from approximately $8 million to over $16 million. Dr. Schoephoerster received his B.S. in Biomedical Engineering in 1985, and his M.S. (1986) and Ph.D. (1989) in Mechanical Engineering, all from the University of Iowa.

Dr. Medhi Shadaram (San Antonio, TX)

Associate Dean of COE Student Affairs and Policies, The University of Texas at San Antonio
Dr. Medhi Shadaram Briscoe is a Distinguished Professor in the Department of Electrical and Computer Engineering at The University of Texas at San Antonio, where he also serves as Associate Dean of COE Student Affairs and Policies. His teaching interests include fiber optic communications, as well as coding and error correction.

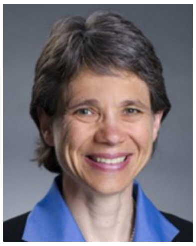
Dr. Shadaram earned his Ph.D. in Electrical Engineering from The University of Oklahoma in Norman in 1984.

Dr. Mark W. Spong (Dallas, TX)

Dean, Erik Jonsson School of Engineering and Computer Sciences, The University of Texas at Dallas
Dr. Mark Spong has led the School of Engineering and Computer Science since 2008, when he was appointed as its fourth dean. He was recruited from the University of Illinois at Urbana-Champaign, where he had taught since 1984.

Dr. Spong received his B.A. magna cum laude and Phi Beta Kappa in Mathematics and Physics from Hiram College, his M.S. in Mathematics from New Mexico State University and an M.S. and Ph.D. in Systems Science and Mathematics from Washington University in St. Louis.

Dr. Sharon L. Wood (Austin, TX)



Interim Dean, Cockrell School of Engineering, The University of Texas at Austin
Dr. Sharon Wood, a structural engineer and chair of the Department of Civil, Architectural and Environmental Engineering, is currently serving as interim dean for the Cockrell School of Engineering. She completed her M.S. and Ph.D. in Civil Engineering at The University of Illinois.

Dr. Wood joined the Cockrell School faculty in 1996 and holds the Cockrell Family Chair in Engineering No. 14. Prior to that, she served on the civil engineering faculty at the University of Illinois at Urbana-Champaign for 10 years. Her technical interests include design and behavior of reinforced concrete structures; evaluation of existing structures; and earthquake engineering. Earlier this year she was inducted into the National Academy of Engineers, one of the highest professional distinctions bestowed upon an engineer.

Appendix B: Alternative Degree Types

A subgroup of the Task Force specifically focused on the topic of new degree offerings. The group ultimately defined four specific alternatives:

1. Outcome-Based Degrees (not based on seat time)
2. Cross-Discipline Degrees (that overlap with business)
3. Step Path to Degree
4. Medical School Modeling (a "practice" plan where industry partners are engaged to train, research, etc.)

"Career-Education" was a concept that threaded together different learning methods, such as completing part of a degree in the traditional manner at school and part in the field and completing hands-on activities. With this model, adjunct faculty might be employees at companies who can teach outcome-based curriculum for all U.T. System institutions, similar to workplace training programs in Europe. The goal is to quickly produce an increased number of qualified engineers who are also job-ready.

Another example to consider is the Texas Tech University School of Medicine model where the school is in Lubbock but the clinical training is in El Paso. In a scenario like this, it is possible for Houston (or another appropriate location) to be the "practice facility" where students gain real-world experience.

Other angles may be to gear the program towards an elite group of students at first (juniors and seniors coming from a certain program or major) to get companies to agree to hire students part-time for two or three years while they are in the program (thus paying students to go to school).

Overall the subgroup supported the idea of a degree-structure that weaves education and career together. A proposed degree could be modeled upon medical school education where after the first two years of education in the classroom, the remaining educational content is delivered in on-the-job settings with the help of practicing physicians. Translation of this concept to engineering would require a close partnership with industry. Under the proposed format, the engineering student could receive two to three years of education in the traditional classroom setting, but then spend another two to three years working part-time in the industry under the mentorship of practicing engineers. The exact format of the sequence could vary from program to program – for example programs could choose to offer sequences of 2 + 3 years, 3 + 2 years, or 4 + 1 years. Under this degree format, the entire engineering curriculum will still be covered to satisfy accreditation agencies, albeit the delivery mechanisms will change and the degree will be based on demonstration of knowledge rather than just class time.

The participating companies would be expected to pay the students for their part-time work at reasonable rates. The companies would benefit because the compensation rates would likely be lower than those for engineers with degrees. The students would benefit because they would earn a salary while obtaining their degree and are less likely to be saddled with onerous student loans.

The practicing engineers could transfer knowledge not only through on-the-job practical training but also through lectures and seminars that could be conducted on site at the company. These mentors could be appointed as adjunct faculty so that requirements by university and accreditation agencies would be satisfied.

The group recommended that since the proposed format would require close partnerships and written agreements with specific companies, such an initiative should be launched at the U.T. System level so that individual universities do not have to negotiate separate contracts. In fact students from various System components could work and study at a company as a cohort, although they would still receive their degrees from their home institutions. The U.T. System could also facilitate housing and other amenities in different cities for students participating in such a program.

The group also discussed that such an engineering facility could be opened in Houston because that city represents a hub of engineering companies, and the U.T. System currently has no engineering presence there. Initially, it would be best to try out this degree-structure as an elite program to attract the best and brightest and to build a high-quality reputation for the program.

Appendix C: Increasing Output by Institution

Each college reported back to the Task Force on the institution's plans for increasing degree production in approximately 10 years, as well as what factors would be necessary in order to do so. Data collected are for the 2011-12 academic year. Ten-year projections were made in 2013, and are therefore for 2023. Summaries of enrollment projections are outlined below, and summaries of annual degree production are shown on the next page. Overall, there is a strong message of growth potential with different pathways for each school.

The current and projected enrollments for each institution are tabulated as follows by the Office of Strategic Initiatives.

Table C.1: Current Engineering and Computer Science Enrollment (2011), and Growth Potential for 2023.

Type of Institution	Institution	Undergraduate Enrollment (2011)	Undergraduate Enrollment (2023)	M.S. Enrollment (2011)	M.S. Enrollment (2023)	Ph.D. Enrollment (2011)	Ph.D. Enrollment (2023)
Research	U. T. Austin	6,751	7,699	733	701	1,695	2,090
Emerging Research	U. T. Arlington	2,447	5,139	1,057	2,114	496	1,240
	U. T. Dallas	2,067	4,051	1,114	2,183	404	808
	U. T. El Paso	2,575	3,554	413	570	197	272
	U. T. San Antonio	3,643	5,500	474	700	283	610
Doctoral	U. T. Pan American	1,500	3,000	205	431	0	50
Master's	U. T. Brownsville	275	687	9	52		
	U. T. Perm. Basin	271	860	11	70		
	U. T. Tyler	568	1,136	94	186		
	TOTAL	**20,097**	**31,626**	**4,110**	**7,007**	**3,075**	**5,070**

Table C.2: Current Engineering and Computer Science Annual Degree Production (2011), and Growth Potential for 2023.

Type of Institution	Institution	Undergraduate Degrees (2011)	Undergraduate Degrees (2023)	M.S. Degrees (2011)	M.S. Degrees (2023)	Ph.D. Degrees (2011)	Ph.D. Degrees (2023)
Research	U. T. Austin	1,209	1,379	519	496	213	263
	U. T. Arlington	303	636	435	870	53	133
	U. T. Dallas	291	570	354	694	58	116
	U. T. El Paso	299	413	160	221	22	30
	U. T. San Antonio	236	356	114	168	18	39
Doctoral	U. T. Pan American	123	213	50	98	0	10
Master's	U. T. Brownsville	22	55	26	12		
	U. T. Perm. Basin	15	48		17		
	U. T. Tyler	568	1,136	94	186		
	TOTAL	**2,598**	**3,870**	**1,682**	**2,623**	**364**	**591**

The figures in the preceding table are summarized below.

Table C.3: Summary of Current and Potential Enrollment and Degree Production Increases.

Degree	Enrollment (2011)	Enrollment (2023)	Enrollment Difference	Degrees (2011)	Degrees (2023)	Degrees Difference
B.S.	20,097	31,626	11,529 (+57%)	2,598	3,870	1,272 (+49%)
M.S.	4,110	7,007	2,897 (+70%)	1,682	2,623	941 (+56%)
Ph.D.	3,075	5,070	1,995 (+65%)	364	591	227 (+62%)
TOTAL	**27,282**	**43,703**	**16,421 (+60%)**	**4,644**	**7,084**	**2,440 (+52%)**

Specific plans for each institution are discussed in the following sections.

The University of Texas at Arlington

Using the 2011 enrollment data as base and averaging the total growth over the proposed 10-year interval, the College of Engineering at U.T. Arlington plans to have an average annual growth rate of 11% of its graduate and undergraduate student population. This rate would result in more than doubling the total enrollment by 2021. Further, the growth rate of 11% equates to an average annual growth rate of 11% in B.S., 10% in M.S., and 15% in Ph.D. enrollments. However, additional resources, particularly space and faculty, are needed to accommodate the projected student population growth. In particular, distance-based digital learning methods will be used as appropriate toward achieving the projected growth.

The College of Engineering at U.T. Arlington has seven departments that will train graduates in high-demand areas including health care, energy, security, and environment. It is expected that the above projected enrollment growth rates will be translated into strategically-apportioned growth rates in the high-demand engineering areas. Concurrent with the increase in engineering student enrollment, the U.T. Arlington College of Engineering will be establishing various additional processes and procedures such as focused student advising and student progress tracking—at all levels—to enhance timely graduation and high retention rate in the student population body.

The University of Texas at Austin

Over the next decade, the key goal at U.T. Austin is to continue increasing the quality in its programs and continue successfully competing with peer institutions as it grows. Modest faculty growth would be necessary to support increases with graduate students, as well as ongoing initiatives to improve graduation and retention rates. Another goal is to increase research productivity while reducing student/faculty ratios.

The budgeted undergraduate enrollment of engineering students (not counting computer science students) is 5,200 for 2014-2015. At the September 12, 2013 Board of Regents meeting, the Cockrell School of Engineering committed to increasing the undergraduate engineering enrollment to 6,640 in 2019-2020 (1,000 students above the actual enrollment in 2012-13). This will be accomplished by adding 50 tenured (or tenure track) faculty spots and 25 full-time lecturers, adjunct faculty members, or professors of practice to the undergraduate program. Construction of the new engineering building is also critical, and U. T. Austin received permission to begin construction in September 2013, with groundbreaking for the new building commencing in January 2015. The new building includes interdisciplinary classrooms, as well as new labs and research areas, which will permit increased enrollment in the Cockrell School. Between 50 to 60 additional classes could be accommodated, in addition to centralized student support services. New technology in this building will also transform communication and learning in high enrollment classes. There will be a shift towards more Ph.D. students than master's students in the future. The school will improve retention of undergraduates through better TA training, implementing electronic media/online teaching models, talking to students about planning more effectively, and aggressively identifying bottlenecks in the system. The plans are based on the assumption that the new building will be completed by Fall 2017. The online market, while uncertain, is still being explored as an option for future master's programs.

Table C.4: Enrollment and Degree 10-Year Projection at U.T. Austin (excluding Computer Science).

	2012-13	2022 Based on Current Dean-Provost Budget	2022 Based on Proposed UG Enrollment Plan
B.S. Enrollment	5,641	5,200	6,640
B.S. Degrees	1,071	1,020	1,290
M.S. Enrollment	722	580	680
M.S. Degrees	450	380	450
Ph.D. Enrollment	1,472	1,740	2,040
Ph.D. Degrees	210	290	340

Notes: *2012-13 numbers based on 2012 ASEE data. Undergraduate degree data are based on projected improved graduation rates. Projected graduate enrollment is based on planned 25/75% split between M.S. and Ph.D. students. Projected Ph.D. degrees based on 6-yr estimated time to degree; projected M.S. degrees based on 3-yr estimated time to degree.*

The University of Texas at Brownsville

U.T. Brownsville is seeing strong growth in its new programs, including engineering physics tracks. Up to 90% of students are bilingual, and there is much excitement around the merger and the potential to offer many more new programs. The school would like to see a gradual increase in graduate degrees, and they think in 10 years they will increase seven-fold. Additional support will be needed to meet this goal, including more space, more faculty (especially since there are only four faculty members now), and being able to leverage relationships from industry to support steady growth.

The University of Texas at Dallas

U.T. Dallas plans to double the College of Engineering over the next 10 years, based on growth figures from the last few years. The college went from two departments five years ago to many more now. The main limitation seems to be space, and because of the rapid growth sufficient lab space is an ongoing challenge. The growth at U.T. Dallas is self-sustaining other than building costs. The Provost returns funds to colleges proportionally based on enrollment, which is a big incentive. Course-specific fees are based on the actual cost of delivering programs, which directly funds and encourages growth (and also penalizes you if you are not growing).

Online learning has also grown from 3% of hours to 8% in the last few years across campus, particularly in the School of Business. All assumptions are being based on getting buildings completed, and the college getting more and more efficient as it grows.

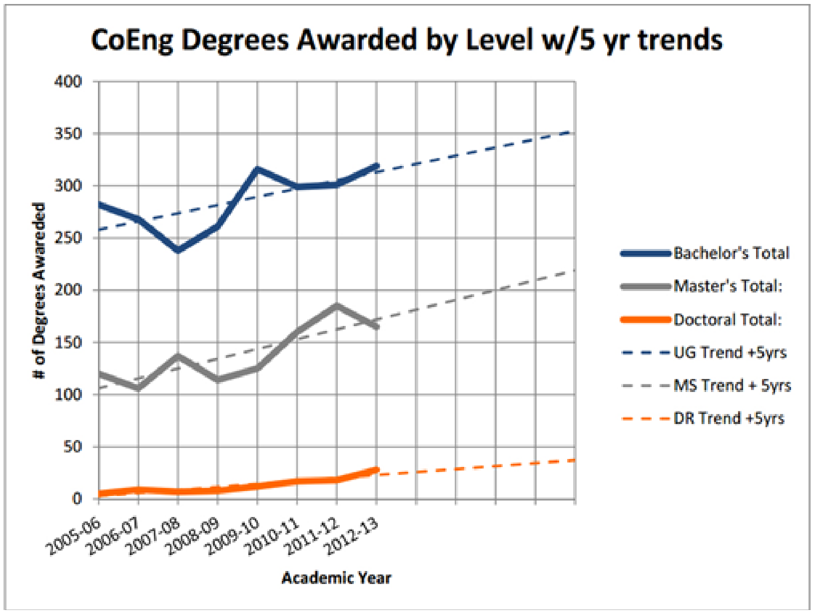
The University of Texas at El Paso

In 2010, U.T. El Paso and the College of Engineering developed a strategic plan for growth over the next decade. The table below summarizes the growth plans for the college, and what will be required to attain that growth.

Table C.5: Current Degree Production Trends at U.T. E. P.

	University		College	
	2010	2015-2020	2010	2015-2020
Performance				
Research Expenditures	$60M	$100M	$12M	$25M
Doctoral Degrees Awarded	60	200	10	40
Master's Degrees Awarded			150	225
Bachelor's Degrees Awarded			300	375
Growth				
Number of Faculty	508	720	75	100
Number of Doctoral Programs	16	40	6	10
Total Enrollment	21,000	29,500	2800	3900
Quality Assurance				
Total Student per Faculty	41	41	37	39
Doctoral Students per Faculty	1	2	1	2
Efficiency				
Research Expenditures per Faculty	$116K	$168K	$160K	$250K
Doctoral Degree Completion Efficiency	0.29	0.39	0.29	0.39

Figure C.1: Computer/Engineering Degrees Awarded by Level with Five Year Trends at U.T. E. P.



In order to reach the performance goals for degree production shown while maintaining quality assurance measures and increasing efficiency, the college must have growth in enrollment to 3,900 students, the number of doctoral programs to 10, and the number of faculty to 100. The number of faculty directly affects the number of students that can be enrolled. Space is also an ongoing issue, and more square footage would be needed to accommodate the increase in students and faculty.

The University of Texas–Pan American

U. T. Pan American is now classified as a doctoral university and the process is underway to develop a new university in South Texas that will integrate U. T. Pan American and U. T. Brownsville. This institution will be a new emerging research institution that will include a medical school and will transform the regional technological and research capabilities. This will further create a unique innovation ecosystem in which the existing advanced manufacturing capabilities of the border region and the College of Engineering and Computer Science will play an important role in creating opportunities for the citizens of the region. The new dean brings a vision of driving technology and innovation while providing opportunities for sustainable economic prosperity in the Rio Grande Valley in South Texas. With four departments and 12 degrees (six undergraduate and six master's degree options), the school has experienced annual growth of over 6% for the last few years.

With this growth, space is becoming an issue. The current building was intended for 1,250 students, and current enrollment is topping out at 1,900. The engineering program has very active K-14 engagement through student organizations and faculty, and has been hiring more faculty recently to support the growth of its new civil engineering program.

To stay on target, there will need to be a minimum increase of 60% in total degrees awarded in the next 10 years. This will take improved public/private partnerships, more collaboration, focused and enhanced student pipeline growth, international relationships, increased endowments, and positioning the school as a college of choice through its quality programs. U. T. Pan American would like to implement a Ph.D. program, as well as implement technology-based entrepreneurial initiatives for students and faculty. New program initiatives would focus on retention, enrollment, research funding, outreach, and infrastructure.

In considering program growth, the following assumptions have been made:

- Continued growth in enrollment up to 3,481 by 2023
- New strategic programs at the graduate and undergraduate levels
- Improvement of the student success rates

The University of Texas of the Permian Basin

The university currently has two programs, mechanical and petroleum, and awarded 22 degrees this year. In 10 years, U. T. Permian Basin hopes to have 130 undergraduate degrees and 25 master's degrees by growing its existing programs and gradually starting new ones (such as bachelor's degrees in chemical and electrical, and a master's in mechanical due to local market demand). The school would like to eventually add online degree options (with in-person labs), as well as competency based options.

New facilities would be needed, specifically an 80,000 square foot engineering building at the U. T. Permian Basin Midland Campus. Corporate sponsorship could be considered for the space. The school currently has seven full-time faculty, which it hopes to grow to 38 (keeping its 21:1 student ratio). To do this, they would need to hire three new faculty members per year.

The University of Texas at San Antonio

Since 2000 there has been a 150% increase at U. T. San Antonio from 1,020 students to 2,503 in 2012. Several new degree programs were recently added (no graduates yet), and projected growth for 2022 includes:

- Increasing Bachelor of Science enrollment from 2,158 to 4,500
- Increasing Master of Science enrollment from 264 to 500
- Increasing Ph.D. enrollment from 132 to 500
- Increasing faculty from 92 to 150

There will need to be more emphasis on graduate programs, particularly at the doctoral level. Additionally, U. T. San Antonio would like to increase its undergraduate graduation rate by 75% in 10 years. The institution does not anticipate large overall growth, so other departments will compensate for the College of Engineering's growth. Better quality of students will lead to better retention. The biggest challenge is finding resources, and while online options will be explored more, the institution considers it more of a supplement to its current coursework than a standalone program.

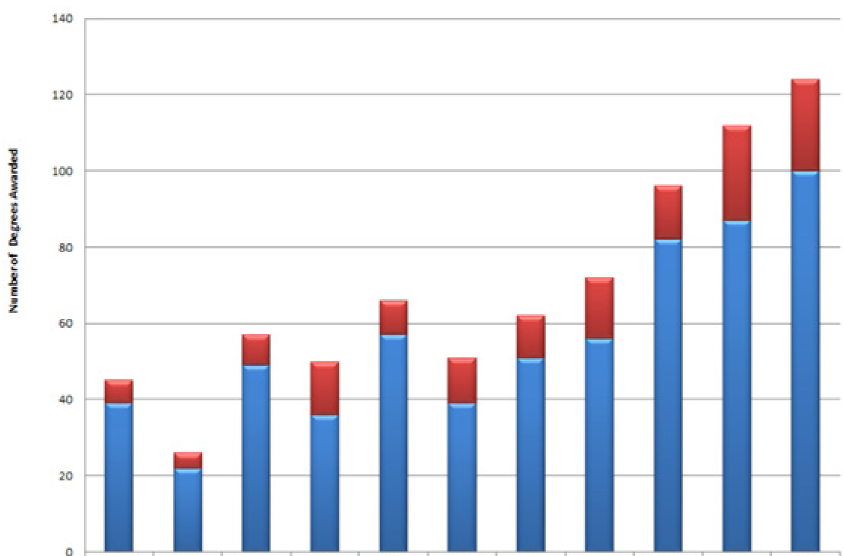
The University of Texas at Tyler

U. T. Tyler would like to double its B.S. and M.S. degrees, which would mean a 60% increase in the undergraduate population. This would include a significant number of transfer students, and increased efforts to keep students enrolled after their freshman year. Student engagement and calculus are issues, but there has been success with summer robotics camps. The school is offering undergraduate programs in conjunction with local community colleges starting this fall. Lab space is limiting, and faculty would need to increase as student enrollment goes up. Online learning could supplement classroom learning but not replace it.

Historic Graduation and Enrollment

The primary consideration of the college is to increase the number of engineering graduates. To achieve this growth in the number of graduates, enrollment will need to increase but not at the same rate as the number of graduates because of the mix among students transferring into the college after approximately two years of study elsewhere and students enrolling as freshmen.

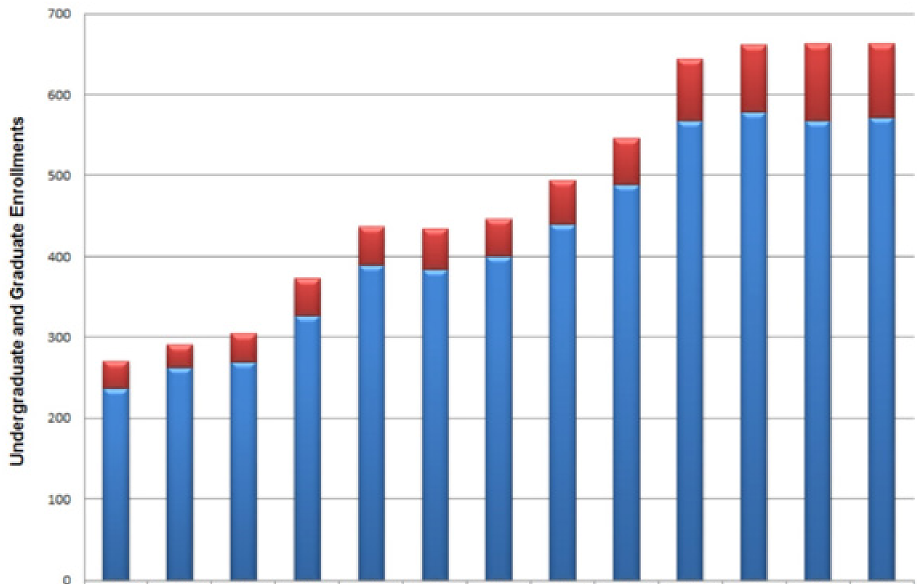
Figure C.2: Historical Graduation Data for U. T. Tyler.



	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
Graduate	6	4	8	14	9	12	11	16	14	25	24
Undergraduate	39	22	49	36	57	39	51	56	82	87	100

Total college enrollments are shown in the figure below. As can be seen, the increase in graduations is not parallel with an increase in total enrollments. This occurs because of the number of students who begin their studies elsewhere and then come to U. T. Tyler to complete their respective degree. This trend has increased in the last few years with the implementation of the statewide articulation compacts, which U. T. Tyler wholly supports, and with changes in the economy. Beginning at a community college and then finishing at a university represents a significant reduction in cost. This change in pathway is very evident in the dramatic increase in the college semester credit hour production. Once past this initial change in pathway, the enrollments are expected to again begin increasing.

Figure C.3: Historical Undergraduate and Graduate Enrollment Data at U. T. Tyler.



	Fall 2000	Fall 2001	Fall 2002	Fall 2003	Fall 2004	Fall 2005	Fall 2006	Fall 2007	Fall 2008	Fall 2009	Fall 2010	Fall 2011	Fall 2012
Graduate	34	28	35	46	47	51	46	55	57	77	83	94	91
Undergraduate	236	263	269	326	389	383	400	439	489	567	578	568	571

Graduation and Enrollment Targets and Capacity

Following are the graduation and enrollment targets for the next 10 years. The strategies for achieving these targets are presented in the next section. The 2010-2011 academic year is the reference year for graduation increase and the Fall 2012 semester is the reference for enrollment increase.

Graduation

Undergraduate Degrees: Double the number of degrees awarded over the next 10 years

Graduate Degrees: Double the number of degrees awarded over the next 10 years

Enrollments

Undergraduate: Increase undergraduate enrollments by 66% over the next 10 years

Graduate: Double graduate enrollments over the next 10 years

Strategies for Increase

Numerous strategies have been and are being implemented to achieve these graduation and enrollment targets.

Undergraduate Retention to Graduation

- Emphasis will be placed on more active engagement of freshmen and sophomores in student organizations. At the same time, faculty will be encouraged to participate in the student organizations so that faculty and students interact socially.
- More engagement in Calculus I and Calculus II: Working with the College of Arts and Science, sections of Calculus I and Calculus II will be offered on a five-days-per-week schedule instead of the meeting schedule. This will provide for more engagement of the students, and will provide more time for lecture as well as problem solving.

Increase Undergraduate Enrollment

- Continue offering camps for high school and middle school students each summer. The camps offered include robotics, introduction to engineering, and Texas Girls Collaborative. The robotics camps that have been offered for the past four years are believed to be the biggest reason that applications for the Fall 2013 semester have nearly doubled in electrical engineering and computer science compared to the same period last year.
- The college will continue to support the statewide transfer compacts and will ensure alignment of its lower division coursework with lower division courses in the ACGM. This will be done to maintain a viable and affordable pathway for students beginning their engineering study at community colleges.
- Beginning in Fall 2013, U. T. Tyler will be offering upper division engineering course work in Houston leading the completion of bachelor's degrees in civil, mechanical, or electrical engineering. The students enrolling in these degree completion programs will account for the greatest increase in college enrollments.
- Work toward an environment in the building that engages the students to make this their "home." This includes better lounge furnishings, study spaces within the complex, and outside tables for study and socializing when the weather is nice.
- Degree programs in Industrial and Systems Engineering and in Chemical and Biomedical Engineering are being considered.
- Offer the undergraduate construction management degree program in a hybrid format. Implementation of this is already in process.

Increase Graduate Enrollment

- Encourage undergraduates to participate in research and encourage them to apply for a graduate program.
- Increase externally-funded research and contracts to provide full assistantships for graduate students. The increases will be in the areas of federal, state, and corporate funding. An emphasis will be placed on technical research to support graduate students pursuing technical master's degrees.
- Have graduate engineering coursework available online so that working students can obtain a master's degree without having to come to campus. This will involve a modest extension of our current online graduate offerings.

Capacity

Sufficient capacity needs to exist to achieve these enrollment and graduation projections. Assuming that the number of faculty will increase to support the increased enrollments, and assuming that sufficient classroom space is available on campus, the critical and most costly constraint on enrollment increase is the availability of laboratory space. If the laboratories are used to capacity, approximately 15 sessions per week per laboratory, the following capacity for the college is estimated:

- The U. T. Tyler campus: Should be able to accommodate 2,000 students
- Houston Engineering Center with current build-out of lease space: 1,000-1,200 students

Appendix D: Discussion of Potential Cost

This Appendix presents a discussion of the potential cost to implement the recommendations contained in this report. There are significant uncertainties associated with estimating cost at this early stage, especially the further out in time for which estimates are made. The discussion presented here is meant to provide the reader with a sense of "what it would take" to implement the recommendations.

Some key parameters that affect costs include the following:

- **Type of expansion.** Costs are different at research-intensive vs. non-research-intensive institutions. For instance, the per-student cost for U. T. Tyler to expand its Houston-based program (a non-research educational program focusing on community college transfer students) is significantly different than the cost for U. T. Austin to expand its degree production (assuming that research must increase in lockstep with undergraduate enrollment).
- **Type of degree or certificate offered.** The cost to deliver a non-degree (e.g., certificate) program may be significantly lower than for a degree program. Whether or not research and/or teaching laboratories are needed, and whether or not online courses are a significant component, significantly affect costs.
- **Different situation at each institution.** Some institutions would increase engineering degree production by expanding the overall enrollment of the whole university. This would typically require new buildings and infrastructure, as well as more people. Other institutions might shift enrollment emphasis and produce more engineers but fewer graduates in other degree programs, perhaps requiring less in terms of new buildings and infrastructure but more in terms of renovation of space.
- **Role of online instruction.** It is recognized that online instruction at scale has the potential to reduce educational costs, but the extent of these potential savings remains to be determined as online offerings continue to expand and be implemented at U. T. System institutions.
- **Houston.** There are several strategies available for expanding the footprint of the U. T. System in Houston, particularly with respect to the energy sector. Investments will be needed to realize this opportunity, but the task force did not attempt to define those requirements at this early stage of conceptualization.

Many of the proposed recommendations, such as expanded engagement with industry, should be self-funding or even generate net revenue that will help offset operational costs.

The key element of cost that warrants discussion is expanded enrollment and degree production. The remainder of this Appendix focuses on the cost of expanded enrollment.

Elements of Cost for Expanded Enrollment and Degree Production

There are three fundamental cost elements for expanded enrollment:

1. Increased operating costs.
2. Need for more buildings, laboratories, and infrastructure.
3. Start-up funding for expanded programs and additional faculty members.

Cost projections would need to be developed by each institution, but generalizations can be made to provide a sense for the potential cost to implement these recommendations. The projections presented below were developed by extrapolating from current enrollment and cost structures to larger enrollment assuming no major changes in operations. It is thought that this estimate is an upper bound on cost. If efficiencies can be realized, costs may be less, as discussed later.

Assumptions

A key cost driver is the number of additional faculty members that would be needed. A typical student-faculty ratio at leading public research universities is approximately 16 to 18. At less-well-recognized and/or less-research-intensive institutions, the student-faculty ratio is more typically 20 to 30. Because the bulk (85%) of current engineering student enrollment at U. T. System institutions is at U. T. Austin and at the four emerging research universities, many of the new faculty will be located at research-intensive institutions. It is reasonable to assume that some efficiencies will be realized via online or blended learning, and through improved sharing of resources between System institutions.

It might be assumed, overall, that the student-faculty ratio associated with implementing these recommendations across U. T. System institutions is approximately 20 students per faculty member. Thus, for each 1,000 additional engineering students enrolled at System institutions, approximately 50 new faculty members would have to be hired. Research-active faculty members require more space and start-up funding than those who are not engaged in research. Many of the new faculty members would be in engineering, but a significant number would need to be hired to teach courses in mathematics and the sciences as well as core courses required of all students at an institution.

Operating Costs

It seems reasonable to assume that the operating costs for expanded enrollment and degree production would be borne by each institution, based on income from tuition/fees suitably set to cover costs for engineering as discussed below, formula funding, and potentially private sources. Each institution would need to assess its own situation, but in principle, operating costs should be capable of being paid from these income streams.

The major components of operating costs include: salaries and wages (faculty, teaching assistants, academic staff, and non-academic staff such as police), benefits, equipment and supplies, information technology, utilities, building and grounds maintenance, library operations, and administrative costs.

The operating costs of academic programs at U. T. System institutions are funded primarily from a combination of State General Revenue appropriations ("formula funding") and tuition/fees. Gift funds are rarely intended to fund core academic operations at public universities, but it may be possible to expand private support (especially from companies that hire engineering graduates). Research is an important source of funds, but these funds are restricted to delivery of specific research outputs and may not be used to support classroom instruction.

There are two challenges with state formula funding. First, the formula funding is based on enrollment in the previous biennium, not the current one, which means that formula funding lags the need for operating funds at institutions with expanding enrollment. Second, it appears that over a period of many years, the growth in per-student formula funding has not increased proportionally with the growth in number of students pursuing higher education at Texas institutions and the rate of inflation.

An increasingly common practice at public research universities in the United States is to charge engineering students a tuition supplement or fee. For example, at U. T. Dallas, such a supplement is charged and has been found to be important in supporting the costs of expanding engineering enrollment. At U. T. Dallas, the current funding structure with the supplement is adequate to sustain additional operating costs associated with expanded engineering enrollment. The situation at each institution is different and would need to be assessed in detail.

Academic Buildings and Infrastructure Costs

New academic space would be needed to accommodate more students. A useful way to estimate space need is to determine average space per student and assume similar figures for expansion. This is essentially an extrapolation of "status quo" programs and may not be valid for innovative programs, such as the U. T. Tyler program in Houston.

U. T. Austin, which is a highly-ranked research university with a large enrollment of Ph.D. students, tends to require more academic space per student than other institutions in Texas. With approximately 8.3 million gross square feet of academic and research space (as reported by the Texas Higher Education Coordinating Board) and 50,000 students, U. T. Austin averages about 165 square feet per student. Several of the emerging research universities in Texas average about 100 gross square feet per student. At some institutions, or with cases involving innovative programs (including online programs), the marginal required space may be below 100 gross square feet per new student.

It seems reasonable, as a first approximation, to assume approximately 100 gross square feet per student for the recommended increase in enrollment. For each 1,000 additional students enrolled, the additional space requirement might be roughly 100,000 gross square feet.

The per-square-foot-building construction cost varies with the type of building and where the building is constructed (available land, access, demolition needs, availability of utilities, construction costs in the locale, etc.). Some buildings will cost more than $500 per square foot, and some perhaps less than $400 per square foot. But in aggregate, an average cost in the range of $400 to $500 per gross square foot seems reasonable to assume in 2013 dollars. Thus, the cost to construct 100,000 gross square feet (enough for about 1,000 additional enrolled students) is about $40 million to $50 million.

While the state might potentially provide some funding for new buildings, and institutions might be able to pay a fraction of the cost for new buildings, it seems safe to assume that the lion's share of the funding would need to come from the Permanent University Fund (PUF). A detailed plan would be needed to project the costs over time, and to include costs for more innovative programs with lower per-student space needs.

Start-Up Costs

There are two elements of start-up cost: (1) program start-up costs (new teaching laboratories and even types of laboratories that are needed when an institution starts a new program, as well as one-time additions to the library and other one-time start-up costs for programs); and (2) faculty start-up costs (typically research equipment that a faculty member must have to be able to attract research).

In terms of program start-up costs, a rough estimate would be that one new program would be started for each additional 1,000 students enrolled, at a typical cost of $5 to $15 million per program (or perhaps an average of $10 million).

As mentioned earlier, expansion of engineering enrollment would require additional faculty members, some in engineering and some in supporting fields such as mathematics. One might assume that roughly 75% of the new faculty members would be research active. The level of start-up funding required for new faculty members varies tremendously – some individuals (typically non-research-active, non-engineering faculty) require a modest amount for computer equipment and a few basics, but an increasing number of science and engineering faculty require more than $1 million for sophisticated laboratory equipment. Perhaps a good average figure across all U. T. System institutions and all the disciplines in which new faculty would be hired would be $400,000 to $500,000 per faculty member. Thus, to put the cost in perspective, for each 1,000 additional engineering students, the U. T. System institutions would need to hire roughly 50 new faculty members (20 students per faculty member), of which approximately 75% might be tenure/tenure track and requiring a total start-up funding of approximately $15 million to $19 million. U. T. System institutions might be able to bear a fraction of this cost, but not the majority at most institutions.

Summary

The rough cost estimates are summarized as follows for each 1,000 additional engineering students enrolled:

- **Operating costs:** Borne by the institutions from income associated with tuition/fees for engineering, formula funding, and potentially private sources – will require analysis by each institution to assess.
- **New buildings and infrastructure:** Approximately $40 to $50 million for each 1,000 additional engineering students, with a portion required from PUF.
- **Start-up costs:**
    - New engineering programs: $10 million for each new program
    - Additional faculty: $15 to $19 million, with significant start-up support from PUF or other sources, for each 1,000 new engineering students.

As a caveat, the cost figures reported herein are rough estimates that are meant to give the reader a sense for "what it would take." The principal uncertainties lie with where and how the growth would take place, as well as the impact of new developments such as expanding use of online instruction that may provide high-quality engineering education.

The status quo regarding cost will undoubtedly change in the years ahead, although it is difficult to predict at this time the extent to which efficiencies can be realized and costs reduced. The U. T. System and its institutions are committed to maximizing productivity, efficiency, and quality. Efforts to bend the cost curve as enrollment and degree production in engineering and computer science are increased will almost certainly continue and intensify. The two most significant opportunities to cut costs from the upper-bound estimates presented above are:

- **Space.** Better utilization of existing classroom space throughout the full week.
- **More Teaching-Intensive Faculty.** Efficiencies could be realized by increasing the number of faculty who are expected to be more teaching intensive (even while contributing to research based on their professional experience).

As an approximation, implementation of strategies such as expanded online learning, greater utilization of professionally-qualified, teaching-intensive faculty, and more efficient use of classroom space could perhaps reduce the cost of operations by approximately 10% and free up 10% of facility capacity. At steady state, additional income from the combination of tuition for engineering and state formula funding should provide the operating revenues needed for expanded enrollment.