Academic Plan for Enrollment
Tier 1 and Tier 2 Narratives
Submission from the College of Engineering / Student Affairs

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On behalf of the College of Engineering Student Affairs, thank you for this opportunity to contribute towards the university's new master plan. Our contributions reflect many different initiatives at the department, college and university levels. At the college level our plans advance goals for increased diversity and improved graduation rates. In an effort to promote a well-integrated master plan, we also include perspectives on new programs, facilities and personnel resources. We recognize the wealth of opportunities to further campus-wide partnerships through this planning process. Significant opportunities for partnering with each college exist in the areas of new programs, facilities and industry involvement.

Opportunities for STEM by Improving Diversity and Retention

Many factors will impact growth opportunities and growth challenges for Engineering in coming decades. The California Demographic Futures report predicts a relative increase in the senior population (aging baby boomers). This puts added pressure on working age professionals (25-64) to help drive the state economy. It also means that many experienced STEM professionals are retiring from the workforce (for example in Aerospace). Meanwhile fewer workers are in the training ages (18-24) due to reduced population growth. Thus fewer are poised to become working age professionals. Amidst this reduction, the state, national and worldwide demand for STEM professionals is increasing (Bureau of Labor Statistics).

Another alarming trend is the reduction in college attendance by students from low-income families, dropping ~10% in the past decade ('California at the Edge', 2009). Population trends (CA Futures) show that the development of the labor force will increasingly rely on CA residents, specifically Latinos. Yet, based on PPIC (Public Policy Institute of CA) Latinos have had historically low rates of college completion. PPIC also points out that 35% of the college-bound students enroll in community colleges.

Hence we see a perfect storm of opportunity. The coming decades are predicted to have an increased demand for STEM disciplines; meanwhile a disproportionately large number of these professionals will be retiring. And the segment of the population that is growing the fastest in CA (Latinos) more typically attend community college, although most don’t complete a 4-year degree. Clearly an opportunity for Cal Poly - with strong benefit to the State - exists by increasing the draw from community colleges, into our STEM majors.
Opportunities to Build on Our Strengths Moving Forward

The statewide statistics suggest an opportunity by increasing our enrollments of transfer students (NTR). How to these students perform at Cal Poly? According to the IR FactBook and Briefcase sources, transfer students to Cal Poly (eventually) graduate at a rate 10-20% higher than incoming freshmen. These transfer students from community colleges are 25% more diverse than the freshmen (FTF). Hence there are immediate benefits to increasing the percentage of NTR relative to FTF enrolling in CENG, benefitting diversity, graduation rates, and the state workforce.

Given a historically low graduation rate for students at community colleges (for 4-year degrees), its appropriate for us to provide additional support service for them. In Engineering we are well positioned to expand our efforts to educate more students from low-income families, and Latino, and female students. Our Multicultural Engineering Program (MEP) and Women’s Engineering Program (WEP) are well-established, long-standing programs. A past study by IR validated the benefit of MEP, showing that it contributes positively to the success of its members, compared to students with similar backgrounds who are not members of the program. Via the efforts of MEP the College currently graduates the 11th most number of Latino students in the nation (ASEE 2012). And via WEP CENG is 19% female, which is on par with the national average for engineering colleges and ranks us 18th in nation for female graduates (ASEE 2012).

Some of our support programming is geared to specifically help students from 1st generation and low-income families. Our STEM outreach summer camp, EPIC (Engineering Possibilities in College) provides opportunities for students to learn about STEM careers and to select a major. Also, we offer a freshman level course to MEP students to help with their transition to campus. MEP also provides additional tutoring and advising services.

Should we aspire to grow NTR enrollment significantly, we do face some challenges. Some of these hurdles are internal to the college, some university-level and some external to campus.

Internal issues have to do with our curricula and how ‘transfer-friendly’ the various programs are. Curricula vary in terms of the best-case time to graduation for a transfer student. This is due to in-depth coverage of material that begins at the freshman level and returns to topics with increasing levels of sophistication in subsequent coursework. The result of this in-depth coverage is long prerequisite chains that extend into the lower division. However there are some ways we can mitigate the time to graduation for transfers. For example, ME created a new course that combines topics from lower division courses to fast track transfer students into more advanced coursework. Obtaining a critical mass for transfer students would encourage similar opportunities in other programs and could improve graduation rates for transfer students.
Another potential benefit to having a few special courses that expedite progress for transfer students is that these courses could help build a cohort. Incoming transfer students have expressed concerns over the lack of a strong community and the related issues of forming study groups and meeting new friends. Common course for incoming transfer students would help build community. Our MEP program also helps build community.

Transfer students enter their program at varying states of progress. Thus they typically need more advising than the average FTF student. In Fall 2013 the College of Engineering established TAP, the Transfer Advising Program to promote success for transfer students. TAP is one of the programs that would require additional resources, should we look to expand transfer students. Resources for MEP and WEP would also need to grow in proportion to their increased student membership.

Campus-wide issues that impact the growth of transfer students stem from the deep investment of faculty to teach in the lower division, for example in CSM and CLA. Thus large shifts in the tradeoff between first time freshman (FTF) enrollment and transfer (NTR) enrollment are a strategic consideration that needs to be guided by the master plan. Another option is to have overall enrollment growth in Engineering be focused more on transfers and less on freshmen. Thus the demand for existing instructional capacity in CLA and CSM would not diminish due to increased transfers in CENG.

An external challenge concerning transfer growth is due to the nature of our relationship with community colleges. While our campus is impacted for NTRs, the pool may not be as deep as needed (depending on our goals for growth). And, an honest assessment of our relationship with community colleges is that we have seriously damaged any partnership that once existed! (Evidenced by interactions at the biannual Engineering Liaison Council meetings, where community colleges vent their frustration with transfer admissions to our Cal Poly representative.) Repairing this relationship will require a multi-year effort. We need to communicate to (select?) community college campuses, to follow through with increased enrollment, and then to repeat yearly. This may help restore our partnerships with community colleges as we gradually deepen our NTR pool.

In the near-term we plan to begin making small shifts from FTF to NTR. We also plan to start rebuilding the relationship with community colleges as we gradually ramp up transfer enrollments. Our TAP advising effort will also continue to further develop needed support services for transfer students.

**Opportunities for Overall Growth of Engineering Programs**
We believe that Engineering may be one of the best-positioned colleges for growth, due to our high volume and high caliber applicant pools. We look forward to a serious discussion in the context of the master plan concerning enrollment growth for Engineering, and the related resource needs.
In addition to the suggestions for growth discussed by our departments, we would like to highlight a few nuanced opportunities. These include new degree programs and the need for expanded facilities.

Strategies for Curriculum Growth via Innovative Programs
Future directions can’t be predicted with any certainty. Nevertheless we can establish mechanisms that enable more flexible growth opportunities in the future. Our General Engineering program (GENE) is one such example. Their curriculum is nimble and adaptable for new opportunities. It previously nurtured and spawned the Biomedical Engineering program, for example. It can serve as a prototyping platform for new courses and interdisciplinary programs, and provides flexibility for enrollment growth. Thus in the context of long-term growth it could provide an opportunity to develop new majors, perhaps including multiple colleges. Chemical or Petroleum Engineering in partnership with the Chemistry Department is a possible example.

Certificate Programs provide tremendous curricular flexibility, to a new audience – industry practitioners. They can provide an opportunity for career growth for these working professionals, as well as a revenue source for the university. When we establish new courses for a certificate program, drawing from existing courses, we can breakdown traditional course boundaries and prerequisite barriers. This can provide access to our many high-end laboratories and facilities to industry practitioners. (Via on-line, then on-campus laboratory experience in summer, for example.) This is a game changer in terms of accessibility to facilities and specialized curricula. Access via a Certificate can be via four courses, rather than a four-year degree.

Collaborative Growth of Facilities
While our current facilities are adequate in terms of square footage, we have serious concerns about the long-term use of an already outdated facility (the AERO Hanger / ARDFA, Building 004). These facilities are dilapidated and failing, yet still heavily used. The prime real estate location may have alternate uses in future plans. It is a focus area for us in the Capital Campaign and we are already working with University Advancement on this effort.

Scaling Personnel Resources
Increased student growth will require additional faculty to meet demand. Beyond just faculty, we need to maintain (and preferably grow) current student to staff ratios for our equipment tech positions. Advising, and MEP staff members already need to increase, and further growth will be needed to support increased student enrollment. This will allow us to expand student support services provided to engineering students. Existing services include transition to college, mentoring, tutoring and career networking. As part of the master plan, we may wish to establish target metrics to help set the number of staff members needed in various areas, as a function of enrollment growth.
Aerospace Engineering Tier 1/2 Narrative

Summary

More so than many other departments or programs at Cal Poly, we believe that our major represents an industry more than a discipline. The Aerospace Engineering Industry is a broad segment of the US and global economy. According to a 2012 report by Deloitte, the Aerospace and Defense industry employs 2.48 million direct and indirect workers, generated $324 billion in sales, and represents 2.23% of the nation’s GDP. The global impact of the industry is even greater. The Aerospace and Defense industry employs a diverse workforce. Within the technical disciplines, graduates with Aerospace Engineering degrees represent a relatively small portion of the hired. According to an Aviation Week Workforce study, only 10% of planned hires are for Aerospace Engineering. In fact, more hires in the field of computer software are planned than any other traditional major. As such our graduates (based on alumni surveys and informal contact with our alumni) find employment in technical positions which range broadly across the industry.

Our goal as a department is to prepare our graduates to work in the Aerospace industry, in contrast to other engineering majors not so tightly coupled to a specific industry. For example, a student with a degree in Mechanical Engineering may work in the automotive industry, the manufacturing segments of the economy, or nearly any other job where mechanical design or analysis is required. The tight coupling between our program and the industry we serve, creates a unique outlook for our program compared to many others at Cal Poly.

We strive to teach our students the fundamentals required by our accrediting agency (ABET) while ensuring the content and applications are in alignment with the current and future needs of the industry. In this context, the Aerospace Engineering department discussed the six Tier 1 and Tier 2 questions with our Industry Advisory Board (IAB) to help guide this narrative.

Overall, we concluded that in 2030 the Aerospace Industry will be working on building complex systems but the specifics of the technical challenges are not yet fully defined or understood. As such, the most important skills we can impart on our graduates is problem definition, problems solving and critical thinking, supported by a strong foundation in the engineering sciences, physics, and mathematics. In addition, the engineering tools of the future will evolve in capability, but nearly all tools will be computer based, therefore, our graduates must develop a minimum level of proficiency with software applications and programming.

The following pages present more detail of the discussions we had as a group during a recent meeting between the Aerospace Engineering faculty and the Aerospace Engineering IAB. In terms of format, we broke into six groups to discuss the Tier 1 and Tier 2 questions. Each small group was asked to discuss the questions relative to the Aerospace Industry and Cal Poly. After a brief report-out to the larger group (with some additional discussion) each group went back and wrote one sentence to summarize their response to the question. The department response to the summary statement completes each section.
Tier 1 – Higher Education Today

a. What forces are shaping Cal Poly (and your discipline) today (which are likely to continue into the future and what new forces may come into play by 2030)?

**Summary:** There will be a diverse student population (not just in ethnicity but also learning skills, communication skills, and other dimensions), which will need to be able to solve the unknown and unexpected problems of the future.

Notes:
- Kids are more collaborative especially using new technology
- Students teaching students and peer learning
  - Mixing student cohorts to foster teamwork across ages and discipline knowledge
  - Getting freshman and sophomores Aerospace experience to get meaningful internships
- Student expectations are that there will be continuous communication and those are the students that L3 (other companies?) want because that they are independent, self-motivated
- Instruction is evolving into more about helping how to manage information then giving knowledge.
  - How to find knowledge
  - How to set up solution
  - How to judge appropriateness of solution
- Quicker transition to applying knowledge to Aerospace to keep students engaged
  - ABET puts artificial barriers to couple math and science with engineering
- Keeping the University funding of in-state students lower than out-of-state students creates incentive to take out-of-state student, which is not in line with the demographic of California ("Ivory Tower" movie)
- One line teaching as a way to make education more affordable
- What resources are available to help students learn how to study and be ready to succeed at Cal Poly (help retain under-represented student population)
- More flexible curriculum

**Department Response:** Faculty will need to continually adapt to the changing learning styles of our future students. In addition, with the availability of information, our role as "gatekeepers" to information will transform into a more collaborative model of teaching and learning. Since the problems of the future are unknown, staying current with our field will be critical to the success of our future graduates. The larger Cal Poly institution must support and develop these capabilities in the faculty and develop student support structures to ensure the success of the diverse student population.

Tier 2 – Projections to 2030

a. Who will our students be in 2030 (e.g. demographics, pre-college preparation)? What are their expectations and interests likely to be?
Summary: The incoming student of 2030 will be the product on the new “common core” education system. They will be highly intelligent with a passion for things that fly and make things work. They will quickly embrace new technologies, but may not have the fundamental understanding of what is behind the technologies. The incoming students will most likely be ethnically more diverse; however, this diversity will most likely not be on par with the diversity of the state in general.

Notes:
- Children of 4-8 years old today
- The students are smarter but not having students with capability to work on open ended problems
- Loss of fundamental capability
- Diversity will continue to grow if the opportunities are exposed and understand the possibilities
- Embrace that people learn differently
- Better connection with industry to what is needed
- Can’t adapt fast enough need to understand ramification of common core

Department Response: The impact of common core standards in K-12 on the future Cal Poly Aerospace Engineering student is not fully understood at the department level. Our curriculum of 2030 needs to be flexible and adaptable to harness the passion of our future students, while maintaining our commitment to teaching and learning of the fundamental engineering sciences, physics and mathematics.

b. What will the global and regional economy be like in 2030 (and how are these forces relevant to your field or discipline)?

Summary: Global and regional trends are moving to a more distributed, less U.S. dominated engineering and manufacturing world. This should not dramatically affect C.P. SLO; this trend has already been occurring over the last 20 years.

Notes:
- Global → U.S. less dominate
  - More industries (engineering and manufacturing) starting elsewhere
    - Could mean more interest in Cal Poly
  - People elsewhere no longer want imports
- Regional → Still a draw for tech in CA
  - Affected by taxes and regulation
    - Regardless don’t see that affecting Cal Poly
- Economy → More automated and additive manufacturing
  - May or may not affect where manufacturing is done
    - Will affect C.P. since design for manufacturing will change
- Aerospace → Defense decline
  - Commercial transport (large) appl. Level
    - Less vs. domin
    - Growth in smaller commercial UAV’s
  - Household appl.
    - UAV’s ?? Computers 40 years ago (The application of UAV technology is as poorly understood as the application of desktop computers was 40 years ago)
Department Response: Within the Aerospace and Defense industry, the issue of globalization has two faces. On the commercial transport segment of the industry, global supply chain and manufacturing has become the norm. However, within the defense segment of the industry, government regulations and security limit the ability of non-US citizens from working in the industry and allowing companies to work globally. At Cal Poly, we will need to find a way to balance these two different approaches within the industry. Overall, we agree the nature of the industry is changing. Billion dollar programs will no longer be the norm. More and more privatization and venture capital investment will occur within the industry.

c. What will we be preparing our graduates to do (in general, and in your discipline) in 2030?

Summary: Prepare students with a fundamental set of skills to be able to contribute on day one and be able to evolve those skills over time as industry evolves.

Notes:
- Higher level of integration
  - Broad exposure
  - Maintain fundamentals
  - Collaboration
  - Prepare to take lead role
- Increased reliance on modeling and simulation
  - Still need first principles
  - Virtual experiment
  - Real experiments
- More global marketplace
  - International partnership “sister university”

Department Response: Consistent with other comments and observations, the specific programs, projects, problems and skill of the future Aerospace Engineer are not fully defined or understood. As a department and as faculty we must continue to stay engaged with the industry as these challenges evolve and stay current in our field. This will be increasingly important as we must ultimately prepare our graduates to be “day-one” ready contributors to the Aerospace Industry.

d. What will our students need to learn to be successful (in general, and in your discipline) in 2030? What level(s) of education will they need (particularly in your discipline) in 2030?

Summary: Student success requires basic fundamental skills that were required in the past and will continue to be required in the future. Problem solving, critical thinking, ethics, learning capability, core engineering employing relevant tools and technologies of the future and will require a master’s level degree.

Notes:
- General: communication (verbal and written), problem solving, critical thinking, multiple capability, ethics, teamwork capability (teaming), understanding not memorization, studying ability, lifelong learning
- In your discipline (Aerospace): fundamental skills in math and science, computer skills, core engineering, specific technologies of specialization relevant to the time period
- Level of education in your discipline (Aerospace): will be Master’s level \(\rightarrow\) 6 year program

**Department Response:** Again, the broad education will continue to be required for success. However, the broad education must be developed in the context of the fundamentals on the workings of the Aerospace Industry. Increasing capability with computers and software will be required. While a MS may be required in the future, we will continue to strive for delivering the best education possible in the traditional four-year degree.

e. What are the implications for emerging fields and integrated learning that goes beyond traditional disciplines?

**Summary:** Emerging fields and integrated learning are going to drive the requirement for a senior experience that is multidisciplinary and requires cross-university (no stovepipes) collaboration culminating in a seminal senior design, build, and test experience. It is the intention that participation in the senior class project will involve many departments.

**Notes:**

We believe two emerging fields are going to be pervasive technologies in aerospace (and other disciplines) are going to be autonomy and UAVs. These will affect every aspect of life and education in 2030. A common characteristic is going to be highly integrated (and complex) systems. For military vehicles, stealth will be a fully integrated technology. There will be a push towards green systems (biofuels) and a significant reduction in carbon footprint. We also talked about characteristics of students in 2030 - very tech savvy, early adapters of new gadgets, "short attention spans" - they are going to be willing to change directions/careers/opportunities every 3-5 years, and are going to expect "instant gratification" or advancement.

This leads us to believe that integrated and multidisciplinary learning. One thought was that the core aerospace/aeronautical curriculum may have to shrink, so that they are prepared for a multidisciplinary career. In terms of working towards a degree, maybe you admit students as "engineer" and don't declare a discipline until after N quarters or semesters. Need to tear down the stove pipes between departments and colleges, and have very broad senior year experience that engages students from across the university into a design, build, and evaluation "project". One example of low hanging fruit, would be collaboration between Agriculture and aero on biofuels. May ultimately want to tie in the trade schools, to have hands on mechanics, technicians and maintainers.

**Department Response:** We believe these comments support our view of Aerospace Engineering as an Industry, not a discipline. Multidisciplinary experiences are the most effective when the solution to a problem requires a diverse set of knowledge. The most relevant culminating senior experience should be driven by the challenges in industry.
Department Strategic Vision: to Design Systems that Improve Global Health

Biomedical engineering is a field that brings together experts in engineering, biology, chemistry, computer science, genetics, medicine, robotics, and other fields to find solutions to some of the most challenging medical problems faced by humankind.

Our areas of expertise impact advancements in Disease Prevention, Diagnostics & Treatment of Human Health:

- Human Motion Biomechanics
- Medical Device Technologies
- Regenerative Medicine
- Bio-micro Systems

Human Motion Biomechanics

- Motion analysis to diagnose healthy exercises for patients with knee arthritis.
- Diagnose muscular activity joint loading during exercise.
- Treat joint deterioration with the design of bio-compatible implants.

Medical Device Technologies

- Enable injured individuals to participate in Team River Runner, an adaptive water sports organization for injured Veterans.
- Treat individuals with spinal cord injuries that destabilize body temperature regulation by designing a long-lasting, light, and portable cooling vest.
- Treat upper-arm amputees by providing a myoelectric-based mouse interface that enables them to effectively control a PC mouse on-screen, using interface sensors attached to the bicep region.
- Poly-grasp prosthetic hand for dextral motion treatment of symbrachydactyly.
Regenerative Medicine

Regenerative medicine is a new way of treating injuries and diseases using synthetically grown tissue and artificial organs.

- Diagnostics with tissue-engineered constructs for in vitro use as preclinical models.
- Treatment of smooth muscle-dependent vasodilation in immature arterialized collateral capillaries.
- Study the prevention of stent rejections with synthetically engineered blood vessels in a scalable, high-throughput manner using adult human cells and electro-spun polymer scaffolds.
- Transplantation of adult skeletal muscle stem cells to enhance the growth of naturally-forming vascular bypasses as a treatment to preserve blood flow following a heart attack or stroke.

Bio-micro Systems

- Clinical diagnostic devices: Lab-on-Chip for point-of-care analysis; development of deployable platforms for in-the-field triage, e.g. viral or stroke market analysis.
- Drug dispensing micro-chips for long-term delivery of medications using biosensing for actuation, e.g. treatment of diabetes.
- Sensor systems as ocular and retinal implants.

What Is Biomedical Engineering?

The National Institute of Health defines bioengineering as "the application of the life sciences, mathematics and engineering principles to define and solve problems in biology, medicine, healthcare, and other fields." Biomedical engineering involves the integration of engineering and science technologies applied to global human health problems. Biomedical engineers design and develop devices and systems that solve health problems. Exact definitions of biomedical engineering can differ slightly. Most academics would agree that biomedical engineering involves using the principles of engineering to develop solutions for health-related products and techniques that improve the quality of life. But from there, it can take off in slightly different directions, depending on the focus of a specific program or research project. Biomaterials specialists are working on ways to grow organs in a lab so people who need transplants won't have to wait for healthy organs to become available.

Government economists expect jobs for biomedical engineers to grow much faster than the average for all careers through 2020. In fact, it will be the third
fastest-growing career. Student demand has led many universities to add programs at the undergraduate, master's and Ph.D. levels. These new degree offerings have drawn many working professionals and medical practitioners back to school, often part-time or on-line, so they can stay current in the profession and get ahead in their careers. For experienced engineers who have already mastered the hands-on aspects of training, online degrees in bioengineering allow them to further their careers without sacrificing continued experience.

http://www.worldwidelearn.com/online-education-guide/engineering/bioengineering-major.htm

Cal Poly Biomedical Engineering Program Stats
Graduates last year: AY13-14 = 111
Admissions Fall 2014 = 1899 Applicants & 89 admitted

Full-time Faculty = 9
Part-time = 3
Lecturers = 4 part-time & 1 full-time

Staff
1 Administrator
Part-time: HR & Finance
1 Technician

Curriculum = 192 units
Major = 55 units (12 tech electives)
CENG Support = 40 units (12 support electives)
Non-CENG Support = 57 units
General Education = 40 units
Communication, Science & Math, Arts & Humanities, Society & the Individual

Average time to graduation = 4.5 years
86% of CENG grads employed within 3-months of graduation
Median starting salary = $60,000

High growth field with a 21% projected growth in employment (US Bureau of Labor Statistics).

Major Fields of employment:
Medical devices and supplies including: prosthetics, artificial organs, joint-replacements, surgical endoscopy and vascular therapies.
Point of care diagnostics: bio sensors
Digital healthcare
Regenerative medicine and tissue engineering
Mechanics of human body: rehabilitation from military or sports injuries

*Cal Poly Strategic Planning for an updated Master Plan 2015-2030*

**Tier 1 Questions**
- What forces are shaping BMED today and may come into play by 2030?

**Tier 2 Questions**
- Who will be our students in 2030: demographics, college-prep?
- What will we be preparing our students to do in BMED?
- What will our students need to learn to be successful in BMED?
- What level of education will students need in 2030?

**Narrative Response**

(1) How will factors affecting higher education impact BMED?

- Explosive growth of knowledge and interdisciplinary programs require extensive foundational training; Bachelor’s + Master’s degrees may become the entry-level into the workforce requirement.

- The average age of CA residents is increasing so the taxable earners will be declining; this will put more strain on state budgets and continue to force universities to provide efficient methods of delivering an education.

- Campus facilities are aging and building projects are requiring university-private sector partnerships. This will continue to make face-to-face education expensive which will make on-line degree options financially more attractive.

- BMED is a laboratory intensive educational program that does not lend itself to on-line learning formats; however, we will need to develop on-line summer offerings for lecture-based courses and consider developing virtual lab experiences.

- Overall, the cost of higher education is increasing and student debt and ROI is becoming challenging; this also limits diversity as lower income students can’t afford Cal Poly; however, resident face-to-face educational experience will continue to provide a high value to students as long as job demand remains strong in CA.

- Cost of living in CA will continue to make it difficult to hire full-time tenure track faculty; the geographic location of Cal Poly will make it difficult to find part-time lecturers. It will be critical that Cal Poly find a way to provide competitive wages to faculty and staff.
(2) Who will our students be (demographics) in 2030?

- Primarily CA residents will be admitted to Cal Poly but there may be an increasing number of out-of-state students at the master's level.

- Not a large increase in international students as the culture of CP and SLO make it difficult for these students to find a socially acceptable environment.

- CA has a diverse ethnicity (majority being Latino, White & Asian) with immigration leveling-off in the next decade. Many young students are coming from a weak K-12 education background which makes it challenging to educate them in 4-years.

- Population growth rate in CA is declining so there will be fewer students entering college and competition for these applicants will increase amongst CSU and UC campuses.

- Cal Poly is not positioned to attract working professionals due to our face-to-face educational pedagogy and our non-metropolitan location.

(3) How will global & national factors impact BMED?

- Global health is an increasing field of study as our population (especially in US and CA) is aging. So, there will be a steady increase in demand for biomedical engineers. A good growth in the job market is predicted.

- We need to increase our student's global awareness of culture, language, politics, economics and their impact on technology.

- Affordable Care Act and the IRS 2012 medical device tax has impact companies' investments in product development and research. In turn this could negatively impact the hiring of biomedical engineering students.

- Public Policy Institute Report (January 2014 www.ppic.org) predicts that demand for educated STEM students will outpace supply in CA thru 2025.

- Cost of education and supply/demand factors will continue to drive Cal Poly to reduce times to graduation. Currently the mean time for a BS in BMED from Cal Poly is 4.5 years and we will need to achieve 5-year graduation rates in excess of 80%.
An aging population, focused on health and quality of life issues, has increased the demand for better medical devices and equipment. Coupled with this long-term trend is an industrial concern for cost efficiency and effectiveness. These problems require the talent of biomedical engineers.

(4) What will future BMED graduates be doing?

- Current data from the U.S. Bureau of Labor Statistics (2014 [www.data.bls.gov](http://www.data.bls.gov)) lists the following industries with the highest levels of employment in BMED: medical equipment, scientific research, pharmaceuticals, electo-medical instrumentation, medical and surgical hospitals.

- Current data from the U.S. Bureau of Labor Statistics (2014 [www.data.bls.gov](http://www.data.bls.gov)) lists the following states with the highest level of employment of biomedical engineers: California, Massachusetts, Texas, Pennsylvania and Minnesota.

- Although many engineering specialties do not require a graduate degree, it is typically recommended or even required for entry-level jobs in bioengineering. The combination of knowledge in biology and engineering is often more than can be mastered in a single undergraduate program. A master's degree is preferred. Doctorates are more typical for those who want to advance into research or teach at a university.

- The Federal Bureau of Labor Statistics counted approximately 16,000 biomedical engineering jobs in 2008, and projected a 20% increase in positions through 2018. Most bioengineering specialists work in manufacturing industries, such as pharmaceutical manufacturing, medical instrument development, and health care supply. Many others work for hospitals, government agencies, or as independent contractors or consultants.

(5) What do BMED students need to learn (competencies)?

- Polytechnic nature of CP can enable us to produce engineers with an integral science, health, agriculture and business background.

- Cal Poly needs to maintain its learn-by-doing advantage and embrace online learning methodologies.

- Changing ITS technology and utilization of digital devices will play a larger role in our educational methodologies.
• This Fall 2014, our Industrial Advisory Board reviewed our curriculum along with our accrediting agency ABET and determined that our curriculum is well positioned to achieve the targeted learning objectives for the biomedical engineering field.

• A biomedical engineer should be a creative, curious problem solver who wants to have an impact on global health. If you like machines, but think the human body is the most interesting machine out there, this could be a great career for you.

(6) How might BMED engage with emerging career fields?

• Biomedical engineers will play a large role in the merging data analytics and digital health fields which are projected to grow significantly in the next decade.

• Biomedical engineers with integrated master's degrees in technology, business and public policy would be well positioned for leadership and management in many of the start-up companies emerging in the global health fields.

• A combined degree in biomedical and manufacturing engineering focused on additive manufacturing is an important field to support the bio-MEMS and nanotechnology markets.

• Biomedical engineering has played a vital role in the development of pacemakers, dialysis machines, developing artificial hips, knees and other joints, along with ultrasound, MRI and other medical imaging techniques.

• The U.S. Bureau of Labor Statistics estimates the average yearly earnings of biomedical engineers as $88,360 in 2011.

• Biomedical engineers are given a foundation to serve at the nexus between technology that impact human health and therefore play a key role in the future of medicine.

bigfuture.collegeboard.org/careers/
The 10 Science & Engineering occupations with the fastest growth rates.
Employment Growth Rates, 2008-2012

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<tr>
<th>Rank</th>
<th>Occupation</th>
<th>Growth Rate</th>
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<tbody>
<tr>
<td>1</td>
<td>Petroleum Engineers</td>
<td>14.9%</td>
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<tr>
<td>2</td>
<td>Astronomers</td>
<td>13.8%</td>
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<td>3</td>
<td>Food Scientists and Technologists</td>
<td>6.8%</td>
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<td>4</td>
<td>Statisticians</td>
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<td>5</td>
<td>Biomedical Engineers</td>
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<td>6</td>
<td>Physicists</td>
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<td>7</td>
<td>Nuclear Engineers</td>
<td>4.6%</td>
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<tr>
<td>8</td>
<td>Biochemists and Biophysicists</td>
<td>4.4%</td>
</tr>
<tr>
<td>9</td>
<td>Software Developers, Applications</td>
<td>4.4%</td>
</tr>
<tr>
<td>10</td>
<td>Aerospace Engineers</td>
<td>4.4%</td>
</tr>
</tbody>
</table>


Summary Recommendations

Biomedical engineering is a new program (started in 2005) and should be ABET accredited by summer 2015. The current curriculum has stabilized and our IAB believes that it will enable our students to be successful in their professional careers for the foreseeable future. Our program provides students with a solid engineering/science foundation along with professional skills (project management, communication, critical thinking, economics & ethics). In the coming decade we plan to develop concentrations (based on technical electives) in biomechanics, bioinstrumentation, bio-micro/nano technologies and regenerative medicine. We offer both bachelor's and master's degrees in biomedical engineering along with master's degrees with specializations in bioengineering and regenerative medicine.

Currently we have approximately 400 student (340 BS and 60 MS) and enroll about 80 first-time-freshman each year; we expect to remain at this level for next 3-5 years. If 3 additional full-time tenure-track faculty were added by 2019, we could increase our enrollment by 50% to 120 first-time-freshman each year by 2022. The Biomedical Engineering Department currently has the lowest ratio of faculty salaries per SCU taught in the CENG. We generate about 12,000 SCU per academic year. We are a very impacted program with a less than 5% acceptance rate for Fall 2014 (applicants/enrolled); so there is a large highly qualified pool of students applying to BMED (median MCA GPA 3.71, SAT 1214). We are planning to develop a strategy for offering summer courses (on-line) that parallel academic-year courses which are highly impacted.
Department Strategic Vision: to Design Systems that Improve Global Health

Biomedical engineering is a field that brings together experts in engineering, biology, chemistry, computer science, genetics, medicine, robotics, and other fields to find solutions to some of the most challenging medical problems faced by humankind.

Our areas of expertise impact advancements in Disease Prevention, Diagnostics & Treatment of Human Health:

- Human Motion Biomechanics
- Medical Device Technologies
- Regenerative Medicine
- Bio-micro Systems

Human Motion Biomechanics

- Motion analysis to diagnose healthy exercises for patients with knee arthritis.
- Diagnose muscular activity joint loading during exercise.
- Treat joint deterioration with the design of bio-compatible implants.

Medical Device Technologies

- Enable injured individuals to participate in Team River Runner, an adaptive water sports organization for injured Veterans.
- Treat individuals with spinal cord injuries that destabilize body temperature regulation by designing a long-lasting, light, and portable cooling vest.
- Treat upper-arm amputees by providing a myoelectric-based mouse interface that enables them to effectively control a PC mouse on-screen, using interface sensors attached to the bicep region.
- Poly-grasp prosthetic hand for dextral motion treatment of symbrachydactyly.
Regenerative Medicine

Regenerative medicine is a new way of treating injuries and diseases using synthetically grown tissue and artificial organs.

- Diagnostics with tissue-engineered constructs for in vitro use as preclinical models.
- Treatment of smooth muscle-dependent vasodilation in immature arterialized collateral capillaries.
- Study the prevention of stent rejections with synthetically engineered blood vessels in a scalable, high-throughput manner using adult human cells and electro-spun polymer scaffolds.
- Transplantation of adult skeletal muscle stem cells to enhance the growth of naturally-forming vascular bypasses as a treatment to preserve blood flow following a heart attack or stroke.

Bio-micro Systems

- Clinical diagnostic devices: Lab-on-Chip for point-of-care analysis; development of deployable platforms for in-the-field triage, e.g. viral or stroke market analysis.
- Drug dispensing micro-chips for long-term delivery of medications using biosensing for actuation, e.g. treatment of diabetes.
- Sensor systems as ocular and retinal implants.

What Is Biomedical Engineering?

The National Institute of Health defines bioengineering as "the application of the life sciences, mathematics and engineering principles to define and solve problems in biology, medicine, healthcare, and other fields." Biomedical engineering involves the integration of engineering and science technologies applied to global human health problems. Biomedical engineers design and develop devices and systems that solve health problems. Exact definitions of biomedical engineering can differ slightly. Most academics would agree that biomedical engineering involves using the principles of engineering to develop solutions for health-related products and techniques that improve the quality of life. But from there, it can take off in slightly different directions, depending on the focus of a specific program or research project. Biomaterials specialists are working on ways to grow organs in a lab so people who need transplants won't have to wait for healthy organs to become available.

Government economists expect jobs for biomedical engineers to grow much faster than the average for all careers through 2020. In fact, it will be the third
fastest-growing career. Student demand has led many universities to add programs at the undergraduate, master's and Ph.D. levels. These new degree offerings have drawn many working professionals and medical practitioners back to school, often part-time or on-line, so they can stay current in the profession and get ahead in their careers. For experienced engineers who have already mastered the hands-on aspects of training, online degrees in bioengineering allow them to further their careers without sacrificing continued experience.

http://www.worldwidelearn.com/online-education-guide/engineering/bioengineering-major.htm

Cal Poly Biomedical Engineering Program Stats
Graduates last year: AY13-14 = 111
Admissions Fall 2014 = 1899 Applicants & 89 admitted

Full-time Faculty = 9
Part-time = 3
Lecturers = 4 part-time & 1 full-time

Staff
1 Administrator
Part-time: HR & Finance
1 Technician

Curriculum = 192 units
Major = 55 units (12 tech electives)
CENG Support = 40 units (12 support electives)
Non-CENG Support = 57 units
General Education = 40 units
Communication, Science & Math, Arts & Humanities, Society & the Individual

Average time to graduation = 4.5 years
86% of CENG grads employed within 3-months of graduation
Median starting salary = $60,000

High growth field with a 21% projected growth in employment (US Bureau of Labor Statistics).

Major Fields of employment:
Medical devices and supplies including: prosthetics, artificial organs, joint-replacements, surgical endoscopy and vascular therapies.
Point of care diagnostics: bio sensors
Digital healthcare
Regenerative medicine and tissue engineering
Mechanics of human body: rehabilitation from military or sports injuries

Cal Poly Strategic Planning for an updated Master Plan 2015-2030

Tier 1 Questions
- What forces are shaping BMED today and may come into play by 2030?

Tier 2 Questions
- Who will be our students in 2030: demographics, college-prep?
- What will we be preparing our students to do in BMED?
- What will our students need to learn to be successful in BMED?
- What level of education will students need in 2030?

Narrative Response

(1) How will factors affecting higher education impact BMED?

- Explosive growth of knowledge and interdisciplinary programs require extensive foundational training; Bachelor's + Master's degrees may become the entry-level into the workforce requirement.

- The average age of CA residents is increasing so the taxable earners will be declining; this will put more strain on state budgets and continue to force universities to provide efficient methods of delivering an education.

- Campus facilities are aging and building projects are requiring university-private sector partnerships. This will continue to make face-to-face education expensive which will make on-line degree options financially more attractive.

- BMED is a laboratory intensive educational program that does not lend itself to on-line learning formats; however, we will need to develop on-line summer offerings for lecture-based courses and consider developing virtual lab experiences.

- Overall, the cost of higher education is increasing and student debt and ROI is becoming challenging; this also limits diversity as lower income students can’t afford Cal Poly; however, resident face-to-face educational experience will continue to provide a high value to students as long as job demand remains strong in CA.

- Cost of living in CA will continue to make it difficult to hire full-time tenure track faculty; the geographic location of Cal Poly will make it difficult to find part-time lecturers. It will be critical that Cal Poly find a way to provide competitive wages to faculty and staff.
(2) Who will our students be (demographics) in 2030?

- Primarily CA residents will be admitted to Cal Poly but there may be an increasing number of out-of-state students at the master's level.

- Not a large increase in international students as the culture of CP and SLO make it difficult for these students to find a socially acceptable environment.

- CA has a diverse ethnicity (majority being Latino, White & Asian) with immigration leveling-off in the next decade. Many young students are coming from a weak K-12 education background which makes it challenging to educate them in 4-years.

- Population growth rate in CA is declining so there will be fewer students entering college and competition for these applicants will increase amongst CSU and UC campuses.

- Cal Poly is not positioned to attract working professionals due to our face-to-face educational pedagogy and our non-metropolitan location.

(3) How will global & national factors impact BMED?

- Global health is an increasing field of study as our population (especially in US and CA) is aging. So, there will be a steady increase in demand for biomedical engineers. A good growth in the job market is predicted.

- We need to increase our student's global awareness of culture, language, politics, economics and their impact on technology.

- Affordable Care Act and the IRS 2012 medical device tax has impact companies' investments in product development and research. In turn this could negatively impact the hiring of biomedical engineering students.

- Public Policy Institute Report (January 2014 www.ppic.org) predicts that demand for educated STEM students will outpace supply in CA thru 2025.

- Cost of education and supply/demand factors will continue to drive Cal Poly to reduce times to graduation. Currently the mean time for a BS in BMED from Cal Poly is 4.5 years and we will need to achieve 5-year graduation rates in excess of 80%.
• An aging population, focused on health and quality of life issues, has increased the demand for better medical devices and equipment. Coupled with this long-term trend is an industrial concern for cost efficiency and effectiveness. These problems require the talent of biomedical engineers.

(4) What will future BMED graduates be doing?

• Current data from the U.S. Bureau of Labor Statistics (2014 [www.data.bls.gov](http://www.data.bls.gov)) lists the following industries with the highest levels of employment in BMED: medical equipment, scientific research, pharmaceuticals, electo-medical instrumentation, medical and surgical hospitals.

• Current data from the U.S. Bureau of Labor Statistics (2014 [www.data.bls.gov](http://www.data.bls.gov)) lists the following states with the highest level of employment of biomedical engineers: California, Massachusetts, Texas, Pennsylvania and Minnesota.

• Although many engineering specialties do not require a graduate degree, it is typically recommended or even required for entry-level jobs in bioengineering. The combination of knowledge in biology and engineering is often more than can be mastered in a single undergraduate program. A master’s degree is preferred. Doctorates are more typical for those who want to advance into research or teach at a university.

• The Federal Bureau of Labor Statistics counted approximately 16,000 biomedical engineering jobs in 2008, and projected a 20% increase in positions through 2018. Most bioengineering specialists work in manufacturing industries, such as pharmaceutical manufacturing, medical instrument development, and health care supply. Many others work for hospitals, government agencies, or as independent contractors or consultants.

(5) What do BMED students need to learn (competencies)?

• Polytechnic nature of CP can enable us to produce engineers with an integral science, health, agriculture and business background.

• Cal Poly needs to maintain its learn-by-doing advantage and embrace online learning methodologies.

• Changing ITS technology and utilization of digital devices will play a larger role in our educational methodologies.
• This Fall 2014, our Industrial Advisory Board reviewed our curriculum along with our accrediting agency ABET and determined that our curriculum is well positioned to achieve the targeted learning objectives for the biomedical engineering field.

• A biomedical engineer should be a creative, curious problem solver who wants to have an impact on global health. If you like machines, but think the human body is the most interesting machine out there, this could be a great career for you.

(6) How might BMED engage with emerging career fields?

• Biomedical engineers will play a large role in the merging data analytics and digital health fields which are projected to grow significantly in the next decade.

• Biomedical engineers with integrated master's degrees in technology, business and public policy would be well positioned for leadership and management in many of the start-up companies emerging in the global health fields.

• A combined degree in biomedical and manufacturing engineering focused on additive manufacturing is an important field to support the bio-MEMS and nanotechnology markets.

• Biomedical engineering has played a vital role in the development of pacemakers, dialysis machines, developing artificial hips, knees and other joints, along with ultrasound, MRI and other medical imaging techniques.

• The U.S. Bureau of Labor Statistics estimates the average yearly earnings of biomedical engineers as $88,360 in 2011.

• Biomedical engineers are given a foundation to serve at the nexus between technology that impact human health and therefore play a key role in the future of medicine.

bigfuture.collegeboard.org/careers/
http://www.bls.gov/oes/current/oes172031.htm

The 10 Science & Engineering occupations with the fastest growth rates.
Employment Growth Rates, 2008-2012
Rank
1 Petroleum Engineers 14.9%
2 Astronomers 13.8%
3 Food Scientists and Technologists 6.8%
4 Statisticians 5.4%
5 Biomedical Engineers 5.4%
6 Physicists 4.7%
7 Nuclear Engineers 4.6%
8 Biochemists and Biophysicists 4.4%
9 Software Developers, Applications 4.4%
10 Aerospace Engineers 4.4%


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Tier 1 and 2 Program Narrative for the Computer Engineering Program

The following document is the tier 1 and tier 2 program narrative for the CPE program. Due to the short timeline of the academic planning discussions, this document reflects only the opinions of the Computer Engineering (CPE) director and a few industry advisory board (IAB) members from the CPE program.

What forces are shaping Cal Poly (and CPE) today (which are likely to continue into the future and what new forces may come into play by 2030)?

Technology will play a greater role in education in the future, with the potential of catering instruction to a variety of learning styles. However, concerns about how technology will be used in education also exist. The CPE IAB is particularly concerned with student’s ability to learn without being distracted by technology – critical thinking takes time and is not well supported by education technology. While online information delivery is highly efficient, it will not replace the lab-intensive nature of the CPE program. Indeed, the lab intensive nature of the learn-by-doing pedagogy is an opportunity.

The continuing decline in state funding for education will also continue to be a challenge. In particular, under-represented minorities (URM) from lower socio-economic groups will continue to be underrepresented in high-quality 4-year institutions due to the high cost of education.

With the increased cost to the student, pressure to increase graduation rates will become of increasing importance. We will require increased analytics to understand student failure modes and need to implement additional support services to ensure students may graduate in a timely manner.

Who will our students be in 2030 (e.g., demographics, pre-college preparation)? What are their expectations and interests likely to be?

In CPE, the student body would be more racially diverse. However, the number of qualified college applicants will also decrease and universities will have to be increasingly competitive to enroll highly qualified undergraduates. These trends likely apply to all programs at Cal Poly. CPE feels that the increased diversity in the workforce will be a positive change due to increased creativity of graduates.
For the CPE program specifically, gender diversity will increase over the current rates, but will likely not approach 50%. Due to the increase student cost of education, job placement will be increasingly important. For the CPE program, this means finding ways to create better links with industry. Possibilities could include the development of a co-op program.

Since talented in-state students will be increasingly recruited by other academic institutions, the CPE program could choose to recruit students from out-of-state and international students. This could have a positive impact on the program’s ability to educate students in issues around internationalization & globalization.

What will the global and regional economy be like in 2030?
Environmental concerns will be increasingly important. Water scarcity and food cost may make it more difficult to employ highly qualified faculty and staff in the CPE program. The following items are opportunities for the CPE program due to changing global and regional trends:

- The design and deployment of environmental monitoring systems will largely be computer-based.
- Large demand for low-cost health care will likely leverage computer-based technologies.
- With an aging population, assistive technologies will become increasingly in demand and will become increasingly computer-based.
- Teaching students how to operate in a global economy will become increasingly important.

What will we be preparing our graduates to do (in general, and in your discipline) in 2030?
Similar to today, these are the following skills our graduates need to have:

- Core technology competency – things that CPE currently does well.
- Communications skills – something that the CPE program needs to work on.
- Ability for life-long learning, in particular the ability to understand new and developing technologies.
- Intellectual curiosity and self-motivation
- Critical Thinking

These are the skills that will be needed by a CPE graduate of 2030, in addition to the current skills:

- Better technical verification/validation tools
- Cultural awareness
- Multi-site global cooperation skills
- Diverse language skills, such as conversational Mandarin.
- Ability to function on multidisciplinary teams.
It is important to note that the “new” skills expected are all in addition to the current skills a CPE student achieves prior to graduation. It is the hope of the program that the general education component of a CPE student’s curriculum could be broadened to include some of these new skills.

**What will our students need to learn to be successful (in general, and in your discipline) in 2030? What level(s) of education will they need (particularly in your discipline) in 2030?**

*What are the implications for emerging fields and integrated learning that goes beyond traditional disciplines?*

Students will need to understand how to integrate computer engineering technology in the future. Ability to analyze and understand large data sets will be important in almost all disciplines and CPE students can play a central role in this aspect. Wearable and mobile computing is on the verge of real widespread adoption and this is a place where CPE students are uniquely equipped. Autonomous vehicles are going to have several embedded computers. Environmental monitoring, Cyber-security, healthcare and expressive technologies will all be areas where CPE students will be developers. A common thread in these emerging fields are a CPE students’ ability to work with people of different disciplines and the need for these students to be socially responsible CPE technology plays an increasing societal role. A MS degree will almost certainly be needed in the future by most graduates and we may find more jobs in computing require a doctorate.
Department of Computer Science

Academic Plan -- Tiers 1 and 2 Program Narrative

Submitted by: Ignatios Vakalis, Chair Department of Computer Science

The department of Computer Science fully supports the Computer Science and the Software Engineering program. Two distinct programs, that share a number of common courses. The department also supports the Computer Engineering program, in conjunction with the department of Electrical Engineering.

The following is a “common narrative” that applies to both Computer Science and Software Engineering programs.

During the last several years, Computer Science as well as Software Engineering, are experiencing a huge increase in the number of applications from prospective students. It must be noted that this monotonically increasing trend has become sharply steeper over the last three years. Also, the industry demand for CalPoly Computer Sc./Software Eng. majors is sharply ascending each year. In particular, for the last 3-4 years, the “CalPoly Career Fair” events are being overwhelmingly populated by companies seeking to hire Computer Science or Software Engineering students as interns or as full time employees. The ascending trends will continue, as the US-Bureau of Labor and Statistics (BLS) predicts that 30% of the new STEM jobs will be in software development alone, as compared to 16% in all of the combined branches of traditional engineering. Also, US-BLS projections indicate that during the 2014-2022 time interval, there will be far more “job openings” than computer science/software engineering graduates. In addition, the US-BLS projections indicate the opposite trend for the rest of the Engineering, and for other STEM fields.

With the current human resources, and current lab facilities, the department cannot satisfy: i) student demand; ii) student interest (from many majors), to enroll in CS/Soft. Eng. courses; iii) demand from employers/companies for the department to educate (many) more students with deep skills in the rapidly changing field of computing /Software Engineering.

How factors affecting higher education will affect your field?
Since student demand and employer demand is and will be steadily (and rapidly) increasing for those majors, current but not adequate funding as well as any future funding decline will have
a plethora of negative effects. The department has experimented with non–traditional (alternative) delivery methods of education. We do not predict they will be “disruptive”, but they provide some partial relief in our huge “student demand” problem. The department embraces technology since after all, the department educates students to design and develop the computing technology of the future.

**Who your students will be?**
As stated, the fields of Computer Science and Software Engineering are growing as computing technology is part of each STEM discipline, as well a key/necessary ingredient for the progression of many other fields: Agriculture, Architecture, Arts/Entertainment, Humanities, Medicine. Thus, we expect many more students seeking to major in Computer Sc./Software Engineering. Future students will be more “technology savvy” (i.e., users of technology), with experiences in desktop, mobile and wearable computing. They will be more ethnically diverse. The department will continue to build on its current success, to ensure a gender balance of students in our field. Due to the location of CalPoly and the great reputation of the department, we expect more out-of-state undergraduate students. We project that non-traditional students will be seeking additional education to enhance their “programming/soft. eng.” skills, as these skills will become necessary for a vast number of sectors of employment.

**How the global context will affect your field?**
Computing is, and become more ubiquitous. It will be part of every human’s life in every continent. Our field needs many more computer Sc./Soft. Eng. who will develop the needed technologies that will give rise (and sustain) new economies in many “under-developed” countries. Also, Computing Technology is and will be playing a pivotal role in educating a massive amount of individuals, residing in less privileged countries. Decisions and future policies on global issues (i.e., environment, pollution, health/spread of diseases, education) will be increasingly relying on the field of Big Data. Computing is the discipline that will create the future technologies for the field of Big Data.

**What your future graduates will be doing? What your students will need to learn?**
Our graduates will be the developers, creators, and architects of future computing technologies (i.e., desktop, cloud, mobile, wearable, augmented reality). Our continuously evolving, “lab rich” curriculum, comprised of the fundamental principles (courses) in Computer Sc./Soft Eng., coupled with an array of technical electives reflecting industry trends, will assure that we graduate “day one ready” CS/Soft. Eng.
As computing (i.e., specialized software development), is and will be a (perhaps the most) critical ingredient for the development of any significance innovation, our graduates are poised to only revolutionize many industries, but also to create new services that will enhance the quality of life. We also project that a number of our future graduates will become “managers of knowledge” as the each discipline becomes more data rich and the field of Big Data is expanding.

We aspire to educate T-shaped Computer Science/Software Engineers. Deep technical knowledge is a must, in order for our graduates to compete in the global terrain. Such knowledge needs to be complemented with: Communication, Collaboration, Leadership, Entrepreneurship/Innovative Thinking skills. Graduates must also exhibit high levels of Ethical behavior and professionalism.

*How your department might engage with emerging fields and interdisciplinary opportunities?*
Computing is rapidly becoming a key component of all STEM fields, as well as a necessary ingredient for the progression of many other fields: Agriculture, Architecture, Arts/Entertainment, Humanities, Medicine. Thus, the diversity of applications and domain areas, makes (applied) computer science/Soft. Eng. critical players in multi-disciplinary teams. Faculty at the computer science department are involved in scholarly/research activities with colleagues spanning every college of CalPoly. This trend will continue and expand. Collaborations with other disciplines, and expansion of multi-disciplinary scholarly activities, are part of the department’s multi-year strategic plan.

The department has spearheaded and is currently implementing a number of initiatives in emerging fields as well as in multidisciplinary programs. Some examples include:

- **Big Data/Data Science**: A unique multi-disciplinary minor between the departments of Computer Science and Statistics. The program is poised to expand and offer opportunities for other majors (i.e., OCOB, COSAM, others). Data science is a strategic, university wide initiative

- **Cybersecurity**: A university wide strategic initiative-- spearheaded by the computer science department. Students from computer science, software engineering, computer engineering are currently involved. As our capacity expands in this “high demand” field, we are planning to educate students from many majors within CENG, and also students from OCOB, CLA and beyond. Various levels of knowledge of cybersecurity will be needed from all CalPoly future graduates
• **Computational Interactive Arts/Game Design:** A unique multi-disciplinary minor between the departments of Computer Science and Art/Design. This minor serves as an (main) pillar in support of the University wide strategic initiative in: Expressive Technologies.

• **LAES:** The department of Computer Science is directly involved with the LAES cross-disciplinary major. One of our colleagues does serve the co-director of the LAES program. Many of the LAES students do choose computer science as the “engineering” part of their LAES studies.

The department is also taking the lead in educating students in specialized emerging fields. Some examples include:

• **Mobile computing** (All platforms: Android, iOS, Windows)

• **Internet of Things (IoT):** IoT is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure. As recently reported: “IoT software platforms will become the rage, displacing the hardware. Much of the early hype has been about cool new sensors, high-tech wearables, and new wireless technologies. Starting 2015, we’ll see increased focus on the software and especially the cloud services to make all these sensors connect, upload data, and drive analytics that generate insights and enable business improvements”.

• **Natural Language Processing:** A fascinating area with enormous applications in mobile computing and beyond.

• **Parallel –Multicore Programming:** A new paradigm in computing/software development that is necessary in the quest to solve real problems in many fields. From weather simulations, to fluid flow, to DNA sequence analysis/matching, to modeling the spread of diseases, to rendering and animation.

• **Augmented /Virtual Reality:** A field that applies in many areas such as: Human Computer Interaction, Mobile Computing, Gaming. In the near future, humans will interact with the augmentation of physical space and virtual space. Computer scientists are/will be the developers of such technology, as it will be applied in various fields.

**Computer Science Education:** The department of Computer Science is planning to take the lead in developing a supplemental certification program (and eventually a single subject certification program), in “computer science” for pre-service teachers. Such effort will require close collaboration between the Computer Science department and the School of Education at CalPoly. Multiple meetings have already taken place with the leadership of COSAM at CalPoly. The CS department is part of a state-wide advocacy group to develop such program.
Facilities:

Since the above narrative is related to the design on new facilities, it is important to note that in order for the computer science department to: i) deliver its mission; ii) educate the ever increasing number of students; iii) provide the education in the emerging fields and implement the multidisciplinary opportunities, the following facilities will be needed:

- Three – four additional Teaching labs (implement/deliver the “learn by doing” paradigm)
- An “Internet of Things / Mobile Computing” Lab
- Upgrades to the “CalPoly- Northrop Grumman Cybersecurity” Lab. Expansion of the research capabilities and space
- A “Security for Embedded Systems” Lab (Renovation of the Raytheon Security Lab)
- A “Parallel/Multi-core Computing” Lab
- A “Virtually Reality Computing” Lab
- A “Motion Capture” Lab (High end cameras, sensors, software for: Games, Computational Interactive Arts, Expressive Technologies)
What kinds of careers will we be preparing our students for? What level(s) of education will they need?

Factors Affecting Higher Education
What are the most important forces shaping higher education today? Discuss those that are most likely to affect public institutions like Cal Poly. Can you anticipate any new forces that may come into play by 2030?

Global and Regional Issues
What are the top continuing and emerging issues that are likely to affect the global, national and regional economy by 2030? Discuss both large-scale and more regional issues that you think are likely to be important to Cal Poly.

What will our students need to learn to be successful in Electrical Engineers in 2030?

I illustrate four trends that will be transformative over the 2015 to 2030 time frame that the Electrical Engineering Department, partner departments and students need to prepare for in order to meet our future needs.

1. Prepare our students and the EE department for the 5th Generation mobile computing and mobile communication environment that is under development.

2. Prepare our students and the EE department for the Power and Energy related governmental mandates that are being implemented.

3. Prepare our students and the EE department for electronic security mandates for our critical infrastructure needs.

4. Prepare our students and the EE department for the International Technology Roadmap for Semiconductors (ITRS) that drives our electronics industry forward.
What level(s) of education will they need (particularly in your discipline) in 2030?

The BS degree will continue to be a marginal entry point with most students eventually receiving an MS degree. Ph.D. education and research will also be strong.

What are the implications for emerging fields and integrated learning that goes beyond traditional disciplines for Electrical Engineers?

1. 5th Generation Wireless Communication and Mobile Computing and its effect on our society;

**Driving force:** New 5G communication systems and mobile communication solutions are being developed. The 5G mobile communication standard development and deployment is schedule for the 2015-2030 time frame.

(from Wikipedia) A new mobile generation has appeared approximately every 10th year since the first 1G system, Nordic Mobile Telephone, was introduced in 1981. The first 2G system started to roll out in 1991, the first 3G system first appeared in 2001 and 4G systems fully compliant with IMT Advanced were standardized in 2012. The development of the 2G (GSM) and 3G (IMT-2000 and UMTS) standards took about 10 years from the official start of the R&D projects, and development of 4G systems started in 2001 or 2002. Predecessor technologies have occurred on the market a few years before the new mobile generation, for example the pre-3G system cdmaOne/IS95 in the US in 1995, and the pre-4G systems Mobile WiMAX in South Korea 2006, and first release-LTE in Scandinavia 2009. In April 2008, NASA partnered with Geoff Brown and Machine-to-Machine Intelligence (M2Mi) Corp to develop 5G communications technology.

Based on the above observations, some sources suggest that a new generation of 5G standards may be introduced approximately in the early 2020s. Key technical hurdles will be spectral allocations and increasing spectral efficiency.

**The EE department needs to update it how it teaches communication system and mobile computing courses to meet the needs of 5G communication systems providers and their supply vendors in the 2030 time frame. Companies such as Apple and Amazon have been very large employers of our graduates in recent years. It is hard to know who will be the industrial leaders in 2030 but it is certain that our information and communication system driven society will continue to rapidly evolve. The electrical engineering department presently has antiquated communication laboratories that focus on analog communication techniques.**
The department needs to invest in a modern communication systems lab in collaboration with the industry partners that drive these changes. The introduction of mobile computing and mobile data communications has had a transformative effect on society. The electrical engineering department needs to offer opportunities to develop mobile appliances including both software and hardware solutions.

The pervasive nature of mobile computing and wireless communications will have a transformative effect on education (We are just at the beginning of this trend!!). Electrical Engineers, Computer Engineers and Computer Scientists need to drive the technology behind these solutions. The Electrical Engineering department along with partners will all need to create solutions and partner with our industrial affiliates to stay current.

The educational implications of 5G mobile communications/mobile computing are also a strong force that will change the way electrical engineering curriculum is taught. Most text books will be purchased online. Everyone will be carrying around a tablet computer with all of their text books available on a single screen. Instructors will be able to project and take notes on their tablets and transfer notes and surveys during class directly with the students. Students will be able to double click on figures in the text book bringing up circuit simulations that are preloaded from information in the figure. The combination text book/computer aided design e-book will be transformative. The students will also have a remote interfaces to electronic test and measurement equipment as an accessory to the tablet. The cost of the electronic test and measurement equipment will be similar to the cost of the tablet itself. Students will be able to do a large set of laboratory experiments wherever they chose and will not be tied to department laboratories except for high performance equipment that is too costly and must be maintained in the department.

Students will have live and delayed streaming video of classes they need to take while they are at their internship at a remote location. Students will also have access to a wide range of courses over the entire CSU network and not specifically tied to our Cal Poly campus for all of their course needs.
2. Renewable Energy Mandates For the State of California and follow-on mandates for other parts of the US.


- 2010 Mandate: 20%
- 2020 Mandate: 33%

**Current Renewable Electricity Mandate:** 20% of electricity generated by 2010[ii] and 33% of electricity generated by 2020.[iii]

**Eligible Resources:** solar thermal, wind, certain biomass, geothermal, certain hydroelectric, ocean wave, thermal and tidal, fuel cells using renewable fuels, landfill gas, and municipal solid waste conversion.[iv]

**Renewable Portfolio History:** RPS originally established in 2002 requiring investor-owned electric utilities to reach 20% renewable retail sales by 2010. On September 15, 2009, the Governor signed Executive Order S-21-09 increasing the requirement to 33% by 2020 (applicable to all utilities). This order also shifted responsibility from the California Public Utilities Commission and California Energy Commission to the California Air Resources Board. The Public Utilities Commission decided in March 2010 to authorize tradable renewable energy credits but placed a moratorium on tradable renewable energy certificate transactions in May 2010.[v]

**Energy Storage Mandate by 2024**

California’s status as the vanguard in pushing energy storage technologies onto the power grid is now official. On Thursday, the California Public Utilities Commission unanimously approved its proposed mandate (PDF) that will require the state’s big three investor-owned utilities to add 1.3 gigawatts of energy storage to their grids by decade’s end.

Now comes the hard part: putting in place a complex set of regulations to guide the development of an unprecedented number of batteries, thermal energy storage and other forms of grid power.
and energy capture-and-release technologies, all keeping to the mandate’s requirement that they be “cost-effective.”

CPUC’s ruling comes after years of work jump-started by a 2010 state law, Assembly Bill 2514, which originally called for the statewide energy storage mandate to enable a “market transformation” for these new technologies.

Large-scale energy storage doesn’t really exist today beyond massive pumped hydro projects. But California’s aggressive renewable energy goals and greenhouse gas reduction mandates will be hard to meet without a lot more energy storage to help balance intermittent wind and solar resources while keeping the grid stable.

The Electrical Engineering Department at California Polytechnic along with collaborating departments must create a strong workforce that can support the renewable energy mandate, energy storage mandate and the transformation of our energy infrastructure for the state of California and the US. The present California energy mandate runs through 2024 but there will be follow-on goals to expand this initiative. The three major utilities, PG+E, SCE and SDGE, will continue to do strong hiring in the area of energy systems. There is also an eco-system of suppliers that support the utilities. In addition, the entire construction industry faces mandates on building techniques and operations that reduce energy consumption in the state. These are major initiatives that will take decades to implement giving a strong employer base for our graduates.

The Cal Poly Electrical Engineering department must develop an updated power and energy system curriculum. The curriculum and laboratory experience must emphasize integration of renewable energy sources, energy storage and smart system components to help our students enter into the power and energy workforce of the future. The Electrical Engineering department should collaborate with Cal Poly facilities and other departments to create a cohesive power and energy strategy that addresses the myriad of disciplines working to address our long term energy needs as a region and as a nation.
3. Cyber Security and Energy infrastructure Security


The Vision: By 2020, resilient energy delivery systems are designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions.

The strategies to achieve this vision confront the formidable technical, business, and institutional challenges that lie ahead in protecting critical systems against increasingly sophisticated and persistent cyber-attacks. Energy companies have long recognized that it is neither practical nor feasible to fully protect all energy assets from natural, accidental, or intentional damage. However, the sector’s track record of excellent reliability reflects an effective protective approach that balances preventive measures with rapid response and recovery. Accordingly, the industry’s vision for securing energy delivery systems focuses on critical functions that, if lost, could result in loss of life, public endangerment, environmental damage, loss of public confidence, or severe economic damage. This prioritized approach is a product of risk-management principles in use throughout the energy sector.

The Electrical Engineering Department must collaborate with other departments and industry as a whole to give our graduating engineers competency on security aspects of energy delivery systems and communication systems in general. The department should build a complementary strategy with computer engineering and computer science to blend both software and hardware solutions that are secure against electronic attack.
4. Semiconductor and integrated circuit roadmap

The International Technology Roadmap for Semiconductors (ITRS) outlines needs for electronic systems in the electrical engineering field. This roadmap is a collaborative effort from a wide range of member companies and governmental agencies in the electronics field. The website documents the many anticipated trends in the semiconductor industry with a long-term outline beyond 2030.

Here is an excerpt from an international technology roadmap for semiconductors (ITRS) road-map report:

The International Technology Roadmap for Semiconductors has emphasized in its early editions the "miniaturization" and its associated benefits in terms of performances, the traditional parameters in Moore’s Law. This trend for increased performances will continue, while performance can always be traded against power depending on the individual application, sustained by the incorporation into devices of new materials, and the application of new transistor concepts. This direction for further progress is labeled “More Moore”.

The second trend is characterized by functional diversification of semiconductor-based devices. These non-digital functionalities do contribute to the miniaturization of electronic systems, although they do not necessarily scale at the same rate as the one that describes the development of digital functionality. Consequently, in view of added functionality, this trend may be designated “More-than-Moore” (MtM).

The Electrical Engineering Department at Cal Poly needs to provide additional training in the area of semiconductor integrated circuit design. In the 2000s, the department’s integrated circuit design effort was complacent and insufficient effort was put in place to educate our students in this area. In the 2015-2030 time frame, electronic functions that were traditionally done at the Printed Circuit board level will continue to be more fully integrated onto a chip. The mix of analog and digital functionality will allow more system-on-a-chip functionality. The high volume markets found in mobile computing and mobile communication areas illustrate this trend very clearly. The EE department will need to adopt more of the tools used professionally in industry. The EE department will need to offer a more complete training curriculum for our students, especially at the MS level in order for our students to be marketable. The materials engineering department has an existing microfabrication facility that is capable of 1 micron lithography. The college of engineering needs to continue to invest in micro and nano-fabrication facilities to help student get hands-on knowledge of continually evolving technology behind our
semiconductor industry. California continues to be a leading center of the semiconductor industry. If the EE department wants to be a relevant player in this area, we will need to upgrade our curriculum and laboratory facilities. Key laboratory facilities will include high performance computing for integrated circuit simulation and a state of the art test facility for integrated circuits that come back for test from the MOSIS (https://www.mosis.com/) fabrication system used in the educational world.
Among engineering programs at Cal Poly, the General Engineering program is uniquely suited for evolving to accommodate development of emerging multidisciplinary fields of study, changes in pedagogy, and enrollment growth. General Engineering has historically served in this role, for example in prototyping the Biomedical Engineering program. General Engineering’s Individualized Course of Study option allows students to develop their own study plan; this flexibility provides a mechanism for curricular innovation in fields which span multiple disciplines. The program has recently completed a major curricular overhaul with the specific goal of creating a solid foundation for future evolution, which includes ABET accreditation and enrollment growth, while maintaining the curricular flexibility that has been so valuable to the College in the past. Three future trends were defined during this process which can be directly supported by the General Engineering program:

<table>
<thead>
<tr>
<th>Trend over next 15-20 years</th>
<th>Support from GENE</th>
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| More students will be interested in a broad engineering background as a foundation for continuing graduate studies or employment in non-engineering fields. | Breadth Degree: General Engineering  
Concentration                                                                           |
| New fields of study will continually emerge that require competency spanning multiple engineering and non-engineering disciplines. | Depth Degree: Individualized Course of Study                                      |
| Department silos will be reduced, and curricular innovation will require cross-disciplinary coordination. | Faculty scholarship in and curricular implementation of college-wide initiatives |

General Engineering Concentration. This is a new concentration which has been designed to meet the needs of students interested in a broad, but rigorous, undergraduate course of study. Students will primarily use this degree as preparation for further graduate/professional studies (e.g. engineering, law, business), engineering careers requiring breadth, and non-engineering careers benefiting from a broad technical background (e.g. education, entrepreneurship, non-profit organizations). Over the next 15-20 years there will be a dramatic increase in demand for programs that provide a solid foundation of engineering as preparation for “something else” beyond a typical discipline-specific engineering degree. An ABET-accredited General Engineering program will be highly sought-after by future students, along the lines of programs such as Harvey Mudd which are entirely “General Engineering”.

Individualized Course of Study. This concentration is designed to allow students the latitude in course selection required to educate themselves in new and evolving interdisciplinary technologies. 40 units of technical elective courses are selected to be consistent with a sharply defined career goal. Study plans selected in the past have emphasized engineering physics, management of technology, bioengineering, ocean engineering and engineering in unique environments. Future trends in technology innovation are clearly multidisciplinary. While we cannot state with certainty what programs will become critical to develop over the next 15 years, the General Engineering program, through the Individualized Course of Study, will allow early
adopters to participate in these emerging fields of study, and allow Cal Poly as an institution to prototype new programs before full-scale launch.

**Mechanism for College-Wide Initiatives.** Although it has not been finalized, the expectation is that, as of the conclusion of this academic year, General Engineering will exist as an independent program residing at the college level. This move enables General Engineering to serve as a mechanism for implementing initiatives that are college-wide, or university-wide in scope. In this role, General Engineering is a key means to support the continual evolution of the institution. There is currently a prototype for this: a TT faculty hired as a joint appointment in OCOB and COE with a focus on Innovation and Entrepreneurship. This faculty member maintains a home department (BMED) for the purposes of RPT, but is appointed to the General Engineering program to serve the needs of the entire college. Other potential examples of General Engineering serving college-wide initiatives include a focus on lower division success via the development of common core curricula shared across departments, and innovation in engineering education through the development of alternative curricula delivery. Beyond undergraduate education, the General Engineering program will grow to serve as the scholarship home for faculty involved in highly multidisciplinary research, including, for example, Big Data, Product Development/Industrial Design, System Sustainability, Autonomous Systems, etc.

**Program Growth over next 15-20 years**
The General Engineering program currently supports nominally 400 students at any given time, but much of this is due to the nature of its unique role as a mechanism for curricular exploration and lower-division mobility. Actual program throughput is 50 admitted students per year, 20 graduated. The qualified applicant pool is extremely deep and is above the average for the college. Upon commencement of the General Engineering Concentration in Fall 2015, these numbers are expected to stabilize at 50 in, 50 out. Upon ABET accreditation, the General Engineering Concentration is projected to be a highly attractive degree, with a 15-yr. Growth Potential of 100 additional students per year. The Individualized Course of Study is expected to remain a “boutique” degree, but can grow to approximately 80 students per year. General Engineering faculty will grow over time to nominally 5-7 rotating positions, each with a 3-year, 50% appointment to support interdisciplinary research initiatives and deliver curricula that has a college-wide scope. It should also be noted that following historical precedent, it is highly likely that the General Engineering program will incubate at least one, and possibly two, entirely new programs over the next 15-20 years. In summary:

*The General Engineering program is by design intended to continuously evolve and track ahead of more traditional single-discipline-based programs. General Engineering and new programs prototyped within GENE can potentially accommodate up to 40% of all College of Engineering growth over the next 15-20 years.*
Tier 1 – Higher Education Today

a. What forces are shaping Cal Poly (and your discipline) today (which are likely to continue into the future and what new forces may come into play by 2030)?

Challenging forces to higher education

Computers and information technology will be available and present in every device we utilize. There will be an abundance of data and information, with various degrees of reliability. There will be a need for individuals with skills to analyze large amounts of data and extract useful information which will enable individuals and organizations to make informed decisions.

The availability of effective communications (video conferencing and telepresence) will change the way we teach classes to a much larger degree that we currently use, and using technologies and methods that are yet to be discovered.

The ability to automate processes will continue to grow, so that processes that are considered complex by today standards will be efficiently automated. An example of this is cars that will drive without human intervention. Individuals who currently make a living from driving vehicles will be out of a job, and will have to acquire other skills – what will those skills be?

As people live longer, there will be a need for increased services for aging populations.

Demand for key resources, such as water, food and energy, will increase, and these resources will become scarcer and more expensive.

Knowledge and technology will continue to change rapidly, so people will need to adapt to change, and will need to keep up to date with new knowledge. The need for life-long learning will become more evident.

Opportunities stemming from higher education trends.

New technologies used in higher education will continue to evolve and improve for the foreseeable future. Cal Poly should invest in adopting some of these technologies and go through the learning curves.
Industrial engineers design and improve business operations, so as organizations adopt and rely more on computers and information technology, there will be a need to prepare industrial engineers to design business operations that make effective use of computers and information technology.

Industrial engineers improve business operations to be more efficient (lean) and have better quality. There will be an increasing need to make health services, hospitals, and services for the aging populations, more efficient and provide better quality.

There will be a need for industrial engineers to increase productivity in the use of limited resources, such as water, food productions, etc.

There will be a need to provide new skills and knowledge (re-train) an older population for new jobs.

**Tier 2 – Projections to 2030**

a. **Who will our students be in 2030 (e.g., demographics, pre-college preparation)?** What are their expectations and interests likely to be? Please include challenging demographic factors and trends and opportunities stemming from these factors and trends.

It is likely that Cal Poly will have a more diverse student population (more Hispanics in California), including a larger international presence.

In another 15 years, technology may be at a point where students may be able to attend classes by telepresence. If that is the case, the pool of students could be larger and more diverse, but so will be the competition from other institutions.

Pre-college preparation is likely to improve, based on the recent efforts to improve STEM education at high schools and community colleges.

**Tier 2 – Projections to 2030**

b. **What will the global and regional economy be like in 2030** (and how are these forces relevant to your field or discipline)? Again, please include challenges and opportunities.

The demand in California for a highly educated workforce will continue to grow.

Manufacturing is likely to change to produce more customized (or customizable) products, such as the iPhone in which the “Apps” can turn the iPhone into a customized device. There will be automated “tailored” shops to buy clothing or shoes that are produce to exact scanned measurements of the customer, for the same cost of today’s mass produced articles.
**Tier 2 – Projections to 2030**

c. **What will we be preparing our graduates to do (in general, and in your discipline) in 2030?** Create a list of activities that are similar to today and activities that will be different from today.

There will be a need for engineers to have the fundamental knowledge of engineering. There will be less of a need to do the number crunching, and more of a need to formulate the analysis and solution approach to problems.

There will be a need for engineers to not just be problem solvers, but also to be able to identify which are the problems that are worth solving (prioritizing).

There will continue to be a need for engineers to work well in teams and collaborate, but perhaps in virtual teams via telepresence and without ever having met the other team members in person.

There will continue to be a need for engineers to be ethical and trustworthy.

There will be an increased need for engineers to find solutions to problems that do not pollute (or actually clean the environment), use less energy (or actually produce energy), etc.

There will be an increased need to develop innovation and entrepreneurship skills in students before graduation.

**Tier 2 – Projections to 2030**

d. **What will our students need to learn to be successful (in general, and in your discipline) in 2030? What level(s) of education will they need (particularly in your discipline) in 2030?**

Specifically in engineering (IE and MfgE):
- Skills to solve problems: identify the root cause, formulate the problem, analyze data, deal with contradicting, unreliable data, deal with variability or uncertainty, evaluate the best solution (technical, economic, environmental and societal), be able to accurately predict the outcomes and consequences of the solution before it is implemented. See ABET Criteria 3 (a) through (k).
- The ability to understand and predict the business implications of engineering solutions.
Communication skills (oral, written) and work in teams and collaborate with others who may not be engineers.

Cultural sensitivity. The ability to work effectively with individuals from other cultures.

Abstract thinking skills. The ability to create abstract models, extract relevant aspects of a problem (reality) into an abstract model for analysis, and problem solving. Then be able to apply or interpret that solution back into the real world, and explain it to non-engineers in clear terms.

Information technology will be fundamental for all engineers, but it will be even more important for Industrial and manufacturing Engineers, who will be using data analysis (Big data, data analytics, etc.) to improve business operations. Industrial engineers will be called to design and improve the information systems to help business make better more informed decisions in a world with huge amounts of data available.

**Tier 2 – Projections to 2030**

e. **What are the implications for emerging fields and integrated learning that goes beyond traditional disciplines?**

There is an opportunity to create a concentration for industrial engineering in information systems design and data analytics. It could be as collaboration between industrial engineering, computer science, statistics, and business.
Materials Engineering (MATE) Program Narrative
Tier 1 and Tier 2 – Higher Education Today and Projections to 2030

Tier 1 – Higher Education Today
What forces are shaping Cal Poly (and your discipline) today (which are likely to continue into the future and what new forces may come into play by 2030)?

The challenging forces to higher education revolve around several “unknowns” and thus one of the most important things that we, as educators and an institution, can do and also to teach our students is how to handle ambiguity and be agile to change. We need to be open to letting go of how things were done in the past (no matter how “successful” they may have been) and being open to trying new ideas in order to adapt to a changing world.

A significant force that is shaping education today and will continue into the future is online learning. Massive Open Online Courses (MOOCS) have the potential to totally change how education is delivered and how people learn. The residential 4-year college may not be the only way for people to earn degrees or the path to secure a job in the future, as the costs and value of college will be challenged.

We should also be considering new cost models. The cost of higher education has outpaced the cost of health care. There is the emergence of alternative cost models that enable people to get degrees at lower cost. How will we begin to create pathways that create lower-cost access?

Like the Common Core, the early adopters are the K-12. For us, this means that freshmen will appear expecting alternative paths to credential their competencies and even degrees. Or, it may be that students who can't see this choice with us will simply choose other institutions.

Overall, there are trends toward localization and customization, including in higher education. If someone studies, say, MATE 210 on their own away from campus, could they be "certified" by Cal Poly as having mastery of MATE 210 by (for example) paying a fee to take (and hopefully pass) a comprehensive MATE 210 exam administered by MATE faculty? Could Cal Poly faculty approve a student's customized plan of study so that someone could earn a degree from Cal Poly (without being physically present on campus most of time) in 2030 in this way?

Blurring of the disciplinary boundaries will be another significant force that will shape us. The realization that the big problems of today and the future are interdisciplinary in nature and are quite complex represents both a challenge and opportunity for the future. The reality of mitigating global climate change and increasing political emphasis on sustainability will be the "norm."
Tier 2 - Projections to 2030

a. Who will our students be in 2030 (e.g., demographics, pre-college preparation)? What are their expectations and interests likely to be?

Our students in 2030 will (hopefully) represent the demographics of our state and include many more first-generation students and female engineering students. Most likely, we'll see more out of state students and international students. There may be many more students that have English as a Second Language (ESL). Perhaps there might even be older students who haven't followed the "traditional" path of going to college right after high school. These students will have a sense of urgency to improve the world, and seek to have direct, positive impact on the world.

There could be a market for older students who may be considering a career change or a need to augment their professional credentials. This may mean offering courses using delivery methods that work for these folks and during times that work for them (e.g., evenings, weekends).

By 2030, we should be getting students who have gone through Common Core (CC) and the Next Generation of Science Standards (NGSS) in the K-12 system. These students may be more prepared than ever for the hands-on, open-ended, and projects-based curriculum at Cal Poly MATE. The students will most likely be very comfortable with learning with technology.

An increase in "helicopter parenting" and people interacting via electronic devices instead of face-to-face may mean that schools and universities may increasingly bear the responsibility for teaching students how to be mature, responsible, and constructive members of a community. Should level of maturity be taken into account (along with academic preparedness) when admitting students into university?

Students will arrive with greater competency in self-directed learning. They will expect and perhaps demand autonomy in their learning process. The traditional lecture classroom will no longer be sufficient (or was it ever?) for engagement of learning. Students will increasingly come with depth of skills that the faculty do NOT have. How will faculty shift the learning experience to accommodate the strengths of the individual student?

Students increasingly arrive with a desire for their work in the world to be meaningful and socially beneficial. Curricula that resonate with these values will be those that attract their engagement.

The MATE program views students as individuals, afforded by its "small" number of students, and understands that each person has their own strengths and ways of learning. Our vision and mission includes "transformative learning" and "cultivates the unique capabilities of each individual." Thus, our different teaching styles and appreciation for how individuals learn may be well poised for the future.
**Tier 2 - Projections to 2030**

b. **What will the global and regional economy be like in 2030?**

The MATE EAB identified the push towards renewable/clean technologies, and a greater emphasis on recycling as part of the economy in 2030. Most likely, there will be new and multiple economic superpowers (not just the US anymore). There will be more global competition for raw materials. In addition, there is the trend towards more distributed manufacturing (e.g., smaller scale printing technology). Additionally, there will be a more mobile economy, meaning that business will be done across the globe, remotely and collaboratively.

Sustainability (and the triple bottom line – the balance of economics, environment, and social equity) will indelibly be important for whatever the global and regional economy might be in 2030.

Manufacturing of commodities will largely be overseas by 2030 (i.e., race to the bottom driven by manufacturing costs), leaving the knowledge economy, localized hands-on expertise in fields that don’t translate well to being on-line (e.g., plumbing), and high quality localized service providers as being key segments of the U.S. economy. Also, the pace of change in many fields is increasing due to the speed and ease with which information can be exchanged.

Emergence of new business models (e.g., b-corps) that draw on the new generations’ desire for livelihood that supports socially-beneficial aims. Possibly, there could be the re-localization of economy and the re-emergence of local micro-industries ("cottage industries"). Niche markets.

The challenge is to create learning experiences that foster the systems thinking, collaboration, creativity, self-directed learning, autonomy and innovation that the new economy requires.

c. **What will we be preparing our graduates to do (in general, and in your discipline) in 2030?**

The graduates of MATE will still do similar work in that they will be the ones with the expertise in materials selection, materials development, and failure analysis. However, there will be a much greater need to know how to substitute key materials (or elements) that might be subject to conflict areas or determined to be toxic to humans or the environment. A “systems” approach to framing and solving problems (i.e., seeing interconnections) will be essential. Also, a sense of caring and responsibility for others and our planet may be as important as the technical skills.

MATE graduates may play a large role in assessing the life cycle of materials and systems, by making decisions of what materials to use, how to manufacture them, and how to dispose/recycle them. They will still need to apply tools and resources
efficiently, and be able to manage large amounts of data in meaningful ways. They will also need to demonstrate adaptive capacity in their job and life.

Graduates in 2030 will need to be able to learn on their own and be able to work with others in different time zones and different cultures. Globalization means that students need to be prepared to work, communicate, negotiate, and lead effectively in a multi-cultural world. Cal Poly may want to invest in offering more foreign language and culture courses, as well as invest in an International Center.

**Tier 2 - Projections to 2030**

d. What will our students need to learn to be successful (in general, and in your discipline) in 2030? What level(s) of education will they need (particularly in your discipline) in 2030?

Our students in 2030 will still need to learn the basics and fundamentals of the Materials Science & Engineering field, as well as the broad knowledge from GE and other support courses. Greater integration in education will be required to address the more complicated problems facing the world. For example, geography, world politics, and cultures are necessary to understand the context for extracting the raw materials from the earth (and often times not in the US) that go into new products. Disciplinary boundaries in higher education need to become more fluid and permeable.

Some disciplinary specific topics of great importance might be:

- product cycle time and transparency
- availability of source materials
- impact of product design and life cycle
- validation vs. inspection
- additive manufacturing
- materials in extreme environments
- computational/simulations (vs. experimental) testing and designing
- appropriate technology

Students will need life-long learning skills that are underpinned by a firm grounding in the fundamentals (math, physical sciences, biology, computer coding), critical thinking and analytical skills, and some hands-on skills. Graduate-level education will likely be needed for knowledge workers and those who aspire to be future leaders in the field. We might consider integrating work experience of some form (e.g., internship, community service, apprenticeship) as part of the curriculum.

The students of 2030 will need to practice the “professional” skills, including being able to talk to and work with colleagues from other disciplines (and also appreciate other professions!). Knowledge of other languages, cultures and customs will be
needed to be able to work globally. Skills in developing relationships will also be needed.

The following are items that our students will need to learn to be successful:
- Life-long learning skills
- Critical thinking and analytical skills for problem solving
- Ability to work and communicate effectively in multi-cultural settings; empathy – (more student opportunities to interact with International Center?)
- Ethics and decision-making - role playing, more explicit integration into senior project
- Creativity and curiosity - open-ended questions, finding ways to evaluate students that supports curiosity and creativity (and the failures that often proceed finding a good solution to a problem)
- Perseverance and grit
- Responsibility and attention to detail
- Strong fundamental math, science, MATE, and computer coding ability
- Incorporating sustainability into problem solving
- Systems thinking across scales (from personal to global);
- Metacognition (awareness of and ability to see one's own mental models, see others' mental models);
- Deep self awareness (knowing one's values and one's conditioned tendencies in the face of conflict);
- Collaboration (distinctions between different modes of team dynamics, power and decision making; awareness of enacting closed/open models of interaction);
- Adaptive capacity (resilience in the face of change; self-change; awareness of change models, ability to constructively work through ambiguity);
- Moral development (capacity to act on principled action v. awareness of professional rules or legal boundaries);
- Transformational learning (learning that fundamentally shifts one's self-identity);
- Embodied leadership (ability to draw on whole body knowing - cognitive, emotional, intuitive);

**Tier 2 – Projections to 2030**

e. What are the implications for emerging fields and integrated learning that goes beyond traditional disciplines?

Since practically all fields (current and emerging) involve the use of materials at some level, MATE can be integrated into the learning of the basic sciences, and offers an opportunity for different ways to deliver course content. For instance materials engineering and solid-state physics have lots of content overlap, and atomic arrangements and bonding in chemistry are the basis for MATE fundamentals. Education research shows that the “need to know” can be a powerful motivator to learn, and thus perhaps curriculum can be modified to present applications and design challenges first in order to drive the “need to know” of the
basic scientific principles. Retention of math and science would improve if learning could be more integrated, rather than segregated into silos.

Multi-disciplinary projects can also provide vehicles for integrated learning. However, current academic structure and how budgets are tied to WSCU’s and WTU’s keep us from trying new ways of teaching/learning.

An emerging technical area is a kind of interdisciplinary engineering at the intersection of chemical/materials/environmental science, with central aims at sustainable innovations around the issues of climate change (water, air, food, energy).

There is a need to identify submerging fields to make room for emerging fields if Cal Poly’s / MATE’s resources & capacity don’t increase or if more creative ways of delivering content are not made. There is also the need for mechanisms and support for experts and students from different fields to easily identify each other and get together to work on multi-disciplinary problems (e.g., a database of experts that can be searched by their areas of expertise, allocation of WTUs within current departmental boundaries that recognizes and rewards cross-disciplinary work).

The faculty must possess the items in 2d in order for faculty to be effective in their roles in facilitating the students’ attainment of the needed skills and knowledge. Faculty must develop the capacity to effectively work in interdisciplinary/transdisciplinary settings. (Transdisciplinary settings are different from interdisciplinary in that they involve varying levels of “expertise,” often including lay people). In addition, there should be awareness and facility with multiple epistemologies. Traditionally, disciplines acculturate people into one of the “3” epistemologies (positivist, constructivist, deconstructivist). Transformational development requires facility with all three.

Capacity to engage in cross-model conversations where one can genuinely suspend one’s point of view and inquire to learn into other models. There is also the need for a courage and humility, which serve as the foundations of moral character. Studies on faculty show that we are typically concerned with interests that are conventional in terms of Kohlberg’s moral development scale. Emerging fields that require integrated learning will likely demand a kind of post-conventional development of the actors engaged in the work in order to be successful.
November 19, 2014

To: Mary E. Pedersen,  
Associate Vice Provost, Programs & Planning

Via: Debra Larson, Dean  
College of Engineering

From: Jim Meagher, Chair  
Mechanical Engineering Department

Subject: Tier 1 and 2 Program Narrative Report

Please find attached the Program Narrative report for the Mechanical Engineering Department prepared by Jim Meagher and Tom Mase.
Tier 1 - Higher Education Today

1a. What forces are shaping Cal Poly (and Mechanical Engineering) today (which are likely to continue into the future and what new forces may come into play by 2030)?

There has been a tremendous reduction in state support for public education. Public support has also eroded with weekly news articles about student debt and exorbitant retirement plans. Universities have responded by raising tuition and recruiting out of state students that pay higher fees. Debt for student loans is at historic levels and is leading people to: question the value of a higher education, expect a clearer return on investment, and demand greater transparency in costs. Universities are responding by reducing costs and increasing solicitations for money from individuals, foundations, and corporations. In order to reduce costs, Universities encourage larger class sizes and are looking to expand participation in online classes. There will be continued pressure for ‘on-time’ graduation and reduction in units toward a degree. Universities are also expanding fundraising activities and looking to create partnerships with industry. Businesses and donors who partner with the university expect to have a role in deciding how their support is to be used. The University is increasingly tailoring its programs, admissions, and expected student outcomes to satisfy business models.

Engineering is considered a professional degree and Cal Poly is considered a Polytechnic University. This makes Cal Poly more attractive to industry but also more susceptible to its influences. The "get a job" mentality will continue to drive programs away from Engineering as a science towards engineering education as job training. The reduction in available funding has also led to a reduction in hiring of tenure and tenure track faculty. More and more classes are being taught by part time lecturers. Salary stagnation is now at a level that we cannot attract top tier diverse talent in faculty.

The trends mentioned above are likely to continue through 2030. Administration is looking for technology to help solve the problem through MOOCS and online education.

MOOCS have already lost the luster they had only a few years ago. It should be expected that they will continue to be used but will still not supplant much of the content of a premier degree. Online education and MOOCS, because of their accessibility, make the world market competitors. Unless one can differentiate themselves from the rest, the market share will go to those with a market lead, a name recognized program, or the capital to support a large infrastructure and marketing. Intranet online classes will probably be the means for those, like the CSU, that can collaborate across a number of
universities, and maintain control of the student degree by requiring units to be from their own campuses.

**Tier 2 – Projections to 2030**

2a. **Who will our students be in 2030 (e.g., demographics, pre-college preparation)? What are their expectations and interests likely to be?**

Cal Poly students in 2030 will still not reflect the local demographics of the county or the state. The next sixteen years will see an urbanization of the central coast but it will still be situated between two larger urban areas that will grow faster. California will still be an expensive place to live with segregated living across ethnic and socioeconomic lines. Cal Poly will continue to attract increasing numbers of out of state students. This will dilute the percentages of students from the growing local proportion of Hispanic background. Cal Poly may start to see more international students - especially students from China.

Pre-college preparation will rely more on the community college system to supplant remedial education and to do more of the lower division coursework. Common calendars and systems (quarter, semester) will be shared by more, if not all, of the CSU. This will make course units, minors, and degrees made from an aggregate of schools possible.

**Tier 2 – Projections to 2030**

2b. **What will the global and regional economy be like in 2030 (and how are these forces relevant to your field or discipline)?**

The US will have the second largest economy in the world behind China. California will continue to have a diverse economy that has large agricultural and technical components. Water and energy will be the dominant challenges. Global warming will be recognized as real and more effort will be placed upon conservation and alternative sources. Reverse osmosis systems will be built in more coastal communities and agriculture in the central valley will be paying more for the water used to grow crops. The consumer automobile industry will have a larger percentage of hybrid and electric cars. All of these challenges and changes will have concomitant changes in local industries. Wind and Solar power will be used more and Nuclear power plants will begin to be built in the US again.
2c. What will we be preparing our graduates to do (in general, and in your discipline)? What kinds of careers will you be preparing your students for in 2030? (What will your graduates be doing at work?) How might this be different from what they do today as a result of the challenges and opportunities identified above?

We will be preparing students to make data driven decisions based upon engineering science. Fundamental understanding of mathematics, physics, chemistry, and mechanics will continue to be the core of an undergraduate degree in engineering. Students will have more integrated higher level tools such as multi-physics software that will combine principles that are now handled separately such as kinematics, stress analysis, electrostatics, and heat transfer. Our students will be preparing for careers in corporations that are even bigger multinational businesses and for smaller entrepreneurial enterprises. The “internet of everything” will be a reality where all our devices are interconnected on the web. This will cause a resurgence of mechatronics as a needed skill for engineering graduates, possibly required by an increasing number of schools. Since industry will play a larger role in the funds coming into the University, they will have a greater say in curriculum. Industries will increasingly pick target schools to build programs that produce the type of graduates they desire.

Tier 2 – Projections to 2030

2d. What will our students need to learn to be successful (in general, and in your discipline)? What level(s) of education will they need (particularly in your discipline)? Discuss the implications and opportunities for Cal Poly’s academic programs, majors and its future students and graduates. Discuss the implications and opportunities for educating students to be successful members of global society. What competencies will our graduates need? What does this imply for the kind of holistic, interdisciplinary education experience that Cal Poly envisions, including its residential community?

How will students get the fundamentally sound training in engineering that is current? The core level of engineering, the laws of physics and mathematics, are hundreds of years old, so those will not change. The same equations Newton proposed in the 17th century are still valid. Such equations are taught in the early part of a student’s education at Cal Poly which will remain unchanged. Teaching methods may change a little, but the relatively unexciting basics will be mastered in the same way.

Augmentation of the fundamentals will come from expanded club and society activities in which students participate. This will happen in all years of a student’s residence. Club and society activities will be as critical for getting good jobs as volunteer hours and essays are to current college applications. University benefactors will donate money and time to extracurricular activities to “give
back" to activities and groups that helped provide them with the edge they had when graduating. Part of the curriculum will be devoted to non-class activities whether it be volunteering or working on CubeSat. This will be much like a technical elective is handled now.

Students will have to experience how to collaborate in a world market for building and engineering products of the future. Part of the world market puzzle will be security and ownership of intellectual property. In summer internships students will be exposed to how the product pipeline traverses multiple continents. International internships or study abroad programs will be essential for the top notch graduate to experience. Students will embrace the new “4 plus 1”: four years at Cal Poly and one year abroad in school or work. Cal Poly will build an international network so that the new 4 plus 1 will be attainable for most students.

**Tier 2 – Projections to 2030**

2e. What are the implications for emerging fields and integrated learning that goes beyond traditional disciplines

Mechanical engineering will always be asked to design and build the things that make people’s lives better. This is true whether on the design/mechanics or energy side of the mechanical engineering house. Whatever the next great product is, iWatch, Google glasses, fuel cell vehicles, exoskeletal transport systems, remote surgery devices, personal space travel, mechanical engineers will be designing and building them. How does the world stay warm or cool in the future? Through HVAC systems designed by Mechanical Engineers. How will third world hospitals be powered, conditioned, and run diagnostic and surgical systems? With things that mechanical engineers design and build.

No matter what game is hot in 2030, biomedical, desalination, space travel, war, peace, energy systems, HVAC, drones, mechanical engineers will have a place at the multidisciplinary table because they design and build the things of life.