**Mechanical Technologies for Sustainability**

- A 2020 Strategic Academic Focusing Plan of ME Graduate Program

**Introduction**

The research in the Mechanical Engineering program in the next 15 years will grow in a targeted area of ***mechanical technologies for sustainability***. We propose three focal areas: 1) sustainable energy systems including renewable energy, energy storage, energy efficiency, and energy transport; 2) sustainable ME technologies for complex mechanical systems, including advanced design and manufacturing, advanced control systems, mechanical properties of new materials, and advanced thermal management systems; 3) sustainable mechanical engineering technologies for interdisciplinary engineering, including bio-MEMS, mechatronics, nanotechnologies, water technologies, biomedical technologies, and air pollution monitoring and control. These technologies are all built on the core strength of ***basic science and engineering*** in the Mechanical Engineering Graduate Curriculum. Hence, such core strengths and competency of the Mechanical Engineering Graduate is essential to the success of the program. The basic research of the Mechanical Engineering program encompasses the areas of solid mechanics, dynamics, controls, thermodynamics, heat and mass transfer and fluid mechanics. These areas are tightly related to the programs of physics, mathematics and biology.

The proposed research theme of ***mechanical technologies for sustainability*** encompasses several interdisciplinary research thrusts on campus. The first example is the research in Environmental Sustainability. This topic is tightly connected to areas of research in thermal fluids, energy, materials, and policy that are of interest to at least 9 of the faculty members in our group (Blanchette, Davila, Diaz, Gopinathan, Lee, Ma, Martini, Modest, Winston). Human health is another example. Two of our faculty members (Li, Goyal) are associated with this research. Cognitive Science and Intelligent Systems is the third example, which is closely related to the work in robots, artificial intelligence, and controls involving four faculty of the program (Carpin, YangQuan Chen, Kallman, Sun). Finally Dynamics of Social and Economic Progress is aligned with the work of one our faculty members (Yihsu Chen).

Some of our faculty’s research is unique on their own right and contributes to the collection of ***mechanical technologies for sustainability*** including the combustion research by Modest, molecular modeling of interface dynamics and tribology by Martini, fractional order dynamic systems by YangQuan Chen, mechanical modeling of biomolecules and other biomechanical systems by Goyal, solar energy technologies by Winston and intelligent HVAC control systems for building energy management by Sun and YangQuan Chen. A new hire coming to Merced in the summer 2014 is specialized at fuel cell technologies. His research will focus on the fuel cell applications for power supply of buildings and for automobiles.

The proposed three focal areas are fit to five defined themes of UC Merced 2020 Project: Energy and Energy Systems, Matter Science and Engineering, Human Health, Environmental Sustainability, and Information, Computational, and Data Sciences, and Engineering.

**Road to Excellence**

To become a world-wide top program in the research of ***technologies for sustainability***, we need to build our core strengths in all basic areas of mechanical engineering.

**FTE Faculty:**

As of Fall 2013, the Mechanical Engineering Graduate Program at UC Merced has 7 ME core faculty and 10 affiliated faculty, totaling 17 FTE faculty, with total 22 graduates (19 Ph.D. students and 3 M.S. students). By 2020, we expect to have

* 40 FTE faculty in ME Graduate Program, among which 25 are ME core faculty and 15 affiliated faculty.
* 110 graduate students.

In order to attract excellent graduate applicants, it is essential for the ME program to be able to offer prestigious and competitive fellowship supports to the first-year graduate students. A major issue in funding graduate students throughout the UC system is non-resident tuition fees. These fees are substantial (over $10,000 more than resident fees) and applied to all non-CA US citizens in their first year of graduate school, and they are applied to all non-US citizens for all pre-candidacy years of graduate school. Unfortunately, a significant proportion of students are not CA residents, and non-US citizens in Engineering. Given that all UCM programs have (or will have) to pay non-resident tuition for students in the first year, we anticipate that the UCM graduate division will design and implement the UCM-wide policy for paying first-year nonresident tuition fees. Furthermore, to attract the best international pool of graduate applicants, a start-up university like UC Merced must engage them early on in their undergraduate programs through summer internships or exchange programs and invest in streamlining their visa processes.

For faculty recruitment, as is the case at the campus level, we need to be able to offer attractive startup packages to hire the best faculty candidates we can find. Further, to bring international impact and competency, we must catalyze international collaborations that may require funds to support MoUs and visiting positions for faculty from international institutions.

**Library Acquisition:**

Although it is clear that additional resources will be eventually needed, it should be possible to start a graduate program without a substantial one-time increase in library funds. The Mechanical Engineering Faculty is taking an active role in the selection of books and journals to be acquired, to ensure that a research-oriented collection is established. It is noted that, as more online resources are taking over the traditional library resource, we should maximize the coverage of our online subscription, for example, Scopus is right now not subscribed. It is also needed to have more faculty involvement in the acquisition process such as “New Book display/review/order room”.

**Computing Costs:**

The engineering programs at UCM emphasize the use of computers in all aspects of the engineering curricula. Due to the increasing importance of computers in the engineering practice, computing is incorporated in all lecture, laboratory and design courses offered. For computational work, the Mechanical Engineering Program would need ample access to high performance computing facilities or resources. Current computing resource is not enough for a growing ME Graduate Program. Efforts are being made to develop desktop supercomputing facility with CUDA-GPU technologies at UC Merced.

**Equipment:**

 ***Graduate Labs***

The Mechanical Engineering Faculty believes that laboratory experience is an extremely important component of engineering education. We observed that the Mechanical Engineering Graduate Program has 0 (zero) lab component in graduate course offering, although they have extensive laboratory training in graduate research. The following principles are proposed to guide our efforts in graduate educational/research lab developments:

1. The labs must reflect the state-of-the-art technology in equipment, instrumentation, computer controls and interfaces, as well as methodology.
2. The labs must reflect a balance between breadth in mechanical engineering, and the focus areas of the Mechanical Engineering Faculty.
3. Certain teaching activities may be conducted in faculty research laboratories. This allows students to be exposed to the current research frontiers and the highly specialized instrumentation and equipment even before entering the proposed mechanical engineering graduate program.

We have identified the following areas that need substantial lab components for graduate education in the next 5 years:

* Nano-fabrication facility
* Mechatronics and robotics
* Sustainable energy
* Rapid prototyping of real time controls
* Advanced thermo-fluids

Additional space should be planned for SoE to allow for starting an Engineering Research Center with extramural funding

**Space and Other Capital Facilities:**

Our consensus on faculty graduate office/lab space is 50 sq ft per student/scholar. Therefore, additional 77x100 = 7700 sq ft lab/office space is needed in the next 5 years at the minimum level. Given 20% (1 in 5) additional visiting scholars/exchange researchers, our total demand for space would be at least 9240 sq ft.

In addition to the above general student seating space, the Mechanical Engineering Program has yet to develop two general support facilities of machine shop and electronics shop.

***The Machine Shop***

The machine shop is an important resource for undergraduate education and graduate research. The equipment in the shop includes 4 milling machines (2 are numerically controlled), 4 lathes, drilling presses and sanding machinery, arc and gas welding equipment, and metal and wood cutting and sawing equipment. We are in the process of acquiring an Electric Discharge Machining (EDM) system, which can be used to fabricate micron-sized components. A dedicated full-time Lab Technician is required for the Electronics Shop.

***The Electronics Shop***

The Mechanical Engineering program has yet to build the Electronics Shop, which can be shared by EECS. A dedicated full time Lab Technician is required for the Electronics Shop.

**Other Operating Costs:**

For a graduate program at the size of 110 students, a full time Graduate Advisor is needed to manage the ME Graduate Program to ensure each student’s program is carefully taken care of.

**Campus enrollments:**

The projected growth of ME graduate students is proportional to growth in the vision. Furthermore, our plans call for the undergraduate enrollment in mechanical engineering to increase from 358 in the academic year 2012-2013 to nearly 800 in 2020, and correspondingly, the faculty will increase from 9 to 25 FTE. A projection for the size of the graduate program considering a healthy ratio of 4 to 5 graduate students per faculty would yield a size of the graduate student population between 100 and 125 in 2020.

**Benefits to the ME Undergraduate Program:**

The proposed graduate program will greatly strengthen the Mechanical Engineering Undergraduate Program in the following aspects:

1. The graduate program is expected to increase the number of funded research projects and interaction with private companies and national laboratories, providing undergraduate and graduate students more opportunities for integrated education through their participation in research projects and internship programs.
2. The graduate program will create a pool of qualified teaching assistants. Currently, there is a shortage of graduate students who are qualified to be TAs for mechanical engineering undergraduate courses, especially for upper division courses. We have tried to hire part-time lecturers from local companies to cover this need.

Furthermore, a mechanical engineering program with significant cross-disciplinary research activities will provide opportunities for the growth of other engineering and science graduate and undergraduate programs.