Ten-Year Review of

DEPARTMENT OF MECHANICAL ENGINEERING

University of Washington

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1. Introduction and Charge

The review of the Mechanical Engineering Department extended over a period of roughly two weeks, starting with the charge meeting on February 23, 2007, and culminating in the site visit on March 8-9. The review committee was charged to assess the academic and educational quality of the Department and to make a recommendation regarding continuing status of the program. In particular, we were asked to consider the following main questions:

- Are they doing what they should be doing?
- Are they doing it well?
- How can they do things better?
- How should the University assist them?

In addition, we were asked to consider questions posed by the Dean of the College of Engineering, particularly regarding the faculty hiring plan.

The review committee carefully examined the self-study document prepared by the Department, the statistics provided by the graduate school, and additional documents that the Department provided in response to committee questions. The UW-internal committee members conducted several meetings with various department constituents and collaborators, including external faculty involved in cross-department collaborations, a group of women students, and a group of minority students. This subset of the review committee also toured some of the department facilities. In some cases, the external members of the review committee were available to participate by phone, and otherwise they were briefed before the site visit. The site visit involved meetings with the department leadership, four faculty research groups, undergraduate and graduate students, members of the department's Visiting Committee, staff, and separate meetings with a few faculty subgroups (women and minority faculty, research faculty and assistant professors). The full committee also toured more of the department facilities at this time.

The report that follows is based on this collection of information and represents the consensus view of the committee members. The report is structured along the following topics: general observations, educational programs, research, strategic plan, faculty recruiting, concerns, and recommendations. There is some unavoidable (and intentional) overlap among some of the sections. Recommendations are found in many of the sections, as well as in the one with that title.

2. General Observations

The review committee was impressed by the considerable progress that the ME department has made in the past five years, especially during the last three under the leadership of Chair Mark Tuttle. The department is moving in the right direction by most measures but there are still issues to confront and ameliorate. Previously, the department had had a history of low research productivity and considerable faculty and staff dissatisfaction. Major issues had been the unconscionably high teaching load borne by the faculty, which was a major factor in stifling

research productivity, and the insufficient number of support staff, both administrative and technical. The teaching load was lightened by reducing the number of students accepted into the department and concomitantly reducing the number of times that courses were offered during the academic year. The staff issue has been addressed by hiring additional personnel, though more are needed.

The department also engaged in the strategic hiring of new faculty, both for tenure track and research positions. These new faculty have been successful in establishing viable, funded research programs and collaborating with more senior, existing faculty. The new faculty have also increased the number of collaborative research activities involving other departments. These hires were guided by the department's strategic plan, which was recently updated.

The ME department currently has many faculty members who are active in research, although there are still some whose research is at a low level or non-existent. One measure of research activity is the level of funding; however, it is not the sole metric. While publications, conference participation, invited seminars, citations, supervision of graduate students, and impact are more important metrics of productivity, funding level is a first-cut indicator, in many cases, of the level of activity and of the likelihood that the other indicators are also favorable. Four of the faculty have established large, well-funded research programs, one of which exceeded $1.5 million of research expenditures in FY 2006. These four programs together accounted for more than 70% of the department's external research funding that year. Although the average external annual funding per tenure-track faculty member (~$200K/year) is still below that at ME departments in peer institutions and other engineering departments at the UW, the increase over the past six years has been pronounced. In addition, significant numbers of ME faculty have received distinguished national and/or international awards over the past decade, have participated in technical society leadership, or have received other recognition for their research, teaching, or service to the profession.

The improvement in funding level (and concomitantly research productivity) was made possible by three factors: the reduction in teaching loads, the success of the new faculty hires, and the hiring of instructional lab staff. On the other hand, based on what the Committee learned during its review of ME, the average rate of publications and PhD production per faculty appear to be still below those of peer ME departments at other universities, but the trend is positive. In particular, the PhD production rate is about half of that in peer departments, namely 0.4 PhD/year/faculty vs. 0.8 at some of the peer institutions. However, one must be careful to consider what the ME "market" for PhDs is in reality. If the department were to double its rate of production of PhDs, would the market be able to absorb them in positions commensurate with their advanced degree?

The undergraduate and graduate program curricula are comprehensive and appropriate for a modern ME department. Adjustments in the curricula to recognize new directions in research are beginning to be made and are expected to continue. The review committee found that the instructional labs have been greatly improved and updated and that space allotted to these labs is adequate for current enrollments; however, these labs cannot support the department's ambitious growth plans. The capstone design experience in the senior year is delivered in various ways, including large group projects such as the SAE Formula race car design project and the human-

powered submarine project (both of which are entered in national competitions, in which the students have generally done well), the mechatronics and fuel cell projects, the new nanotechnology project, and smaller projects which are sponsored by local and west-coast industries.

Overall, the morale of the department appears to be good, with staff morale somewhat higher than that of the faculty. The faculty's points of contention lie primarily at the College and University levels, as they largely involve dissatisfaction with salary and research space. The junior tenure-track faculty are doing very well and are happy with the support they receive from their senior colleagues, the Chair, and the staff. However, concerns were expressed by some of the research faculty about their perception that they are less than fully integrated into the department and are not treated as equals compared to the tenure-track faculty. This was particularly the case with junior research faculty. Most of the research faculty perform their work in buildings other than MEB or off campus; thus, physical separation from the tenure-track faculty may play a significant role in this issue.

The department has had only one faculty retention problem in the recent past, but this is likely to change as the reputation of the department and quality of the junior faculty improve. Retention is likely to be a problem with research faculty in the near term.

The climate for diversity in the department is excellent and to be commended. Women and minority students and faculty reported that they feel included and valued. A separate determination of the diversity climate for staff could not be made because of time constraints, but the committee's meeting with all the departmental staff did not reveal any problems in this regard. Neither did any staff member ask to meet with the committee separately. Accordingly, the committee feels that the diversity climate for staff is also positive. The very favorable diversity climate does not mean that there is no room for improvement; in fact, the number of women and minority faculty, students, and staff should continue to be increased. The department recognizes this issue and has instituted mechanisms to attain short- and long-term diversity goals, as described in its self-study report.

All members of the department and the Visiting Committee expressed great satisfaction and confidence in the leadership of Mark Tuttle, who has been at the helm since July 2004, and feel good about being part of the department. These feelings were palpable at the level of each of the constituents of the department – faculty, staff, and students.

As noted earlier, the generally positive impressions that the ME department left with the review committee do not imply that there are no areas of concern. There *are* issues that need to be addressed to bring the department to the next level of excellence. In fact, these issues can be considered to actually be opportunities for departmental enhancement. Areas requiring improvement are addressed in Section 7, and recommendations are made in Section 8.

3. Academic Programs

Undergraduate Program

The undergraduate program is not listed among the 24 ME departments which were reviewed by US News & World Report for its 2007 rankings; thus, it is difficult to comment on how the department is perceived relative to its peers, other than to state that it is ranked below 24th.

The department is doing a good job of educating students in the fundamentals of mechanical engineering and provides excellent opportunities for real-world experiences through the available capstone design courses. The undergraduate curriculum is comprehensive and appropriate for a modern ME department. Adjustments in the curriculum are being planned to recognize new directions in research and are beginning to be made. These changes are being implemented first in the graduate curriculum and are planned to trickle down to the undergraduate level. The instructional labs that support the classroom work have been greatly improved and updated in recent years. Although space allotted to these labs is sufficient for the department's current enrollments, it will not be able to adequately support the department's ambitious growth plans.

The department is justifiably proud of its large machine shop devoted to students, with state-of-the-art equipment thanks to generous gifts from corporate sponsors. There is a long-term plan for updating equipment that is financed in part by student course fees but also relies on continuing industrial gifts. The technical staff who support the labs are very good and play an important role in the educational mission of the department. There is a need for another lab engineer to offer more hours for the machine shop and avoid lab closings due to illness, but apparently hiring plans are already in place.

The department might consider sharing some teaching labs with other departments, both for space and cost savings, and perhaps also consider sharing some courses that have common elements. The College as a whole can benefit by combining teaching laboratories for courses with similar content. The College's Controls programs already share instructional lab space and have done so very successfully for more than a decade. Potential sharing opportunities also exist in fluid mechanics and heat transfer (Aero. & Astro. and ME) and in structures and materials (ME, Aero. & Astro., CEE, and MSE). Sharing laboratories presents its own set of challenges but these can be overcome, as was demonstrated by the consolidation of the controls labs. Joint-listing courses at the undergraduate level may be desirable in theory but presents greater difficulties, due to the more pronounced differences in topical emphasis among departments, as compared to graduate courses. For example, despite repeated attempts at joint-listing the senior-level courses in controls in AA, EE, and ME, success has proven elusive, and the three departments reverted to teaching their own separate controls courses. At the graduate level, on the other hand, controls courses have been joint-listed successfully for many years.

As noted earlier, the capstone design experience in the senior year is delivered in various ways, including large group projects such as the SAE Formula race car design project and the human-powered submarine project (both of which are entered in national competitions, in which the students have generally done well); the research-driven mechatronics, fuel cell, and nanotechnology projects; and smaller projects which are sponsored by local and west-coast

industries. The department's industrial constituents are happy with the capstone projects (and the ME program in general). Recent curriculum innovations, which have been driven largely by the capstone courses, include:

- Hiring an instructional technician to direct students in labs, train TAs and maintain equipment, aimed at supporting the department goal of increasing experiential learning. This hire was deemed by faculty, staff, and students to be a very good move.
- Developed new capstones in the areas of nanotechnology and mechatronics, which better integrates research and education efforts.
- Developed a fuel cell lab to support the fuel cell capstone.
- The ME Leadership Seminar Series, featuring successful alumni as speakers, helps students learn about career options and to connect with alumni, and is much appreciated by the students.

Although some undergraduates participate in research, mostly through NSF REU awards, there is little documentation of these efforts, and there are no data on the percentage of students who undergo at least one quarter of research experience. Research experience is an excellent adjunct to the capstone experience and should be encouraged and better documented.

Effective advising is a very important aspect of any undergraduate program. On this issue the ME department's performance is mixed. As is the case for most departments in the College of Engineering at the UW, a large percentage of academic advising tasks is handled by department staff members who do not have engineering backgrounds. This situation is not disadvantageous per se, so long as faculty are readily available to provide guidance on curriculum details and choices, projects, capstone courses, and other matters pertaining to the students' technical education. Interestingly, student-faculty interaction is perceived to be healthy and strong, with both students and faculty expressing satisfaction, but this appears to relate to interactions in classes and in research or capstone experiences, not to advising. The committee has some concerns about possible access problems to advising staff and the lack of faculty involvement, as noted in Section 7 of this report.

Teaching effectiveness is another important aspect of a strong undergraduate program. The ME department has several mechanisms for assessing learning and teaching effectiveness, in part associated with ABET and university requirements. In general, teaching evaluations fall within the norms seen in the College as a whole, with similar variances. As in every department, some faculty consistently receive very high student evaluations, while some other faculty are found at the other end of the ratings spectrum. Most of the faculty receive respectable evaluations. The department also conducts an exit survey that would be useful in assessing how its graduates are doing in meeting program objectives, if only the results were routinely analyzed. The lack of analysis of the exit surveys represents a lost opportunity; thus corrective action should be taken immediately.

<u>Student Issues</u>:

Approximately 50% of undergraduate applicants are accepted into the department (as juniors), and roughly 70% of these enroll, resulting in an entering class of about 100 per year. The

department offers 40 scholarships to undergraduates per year, an excellent level of support. Although the department does not currently admit freshmen, it is open to doing so in the future provided that more resources are made available, particularly for advising. Not only will additional staff be required to adequately handle the greatly increased influx of students, but also new office, computing, and other space will be needed.

While the undergraduate program duration is nominally four years, as it is in all departments, a few students suggested that it can easily turn into five or more years without careful advising, because of pre-requisites and limited course offerings (currently most ME courses are offered twice yearly and a few are offered only once; this is in contrast to the time when all courses were offered every quarter and several in the summer, but that level of course availability was not sustainable for faculty also expected to do significant research). The undergraduates would like pre-requisites for capstones to be offered in all quarters, but the problem can be addressed effectively through more strategic timing, such as moving one or more of the offerings to autumn.

The rigidity of the curriculum may hinder students from doing interdisciplinary work. This issue impacts the potential for students to make meaningful research contributions, but also ignores the fact that engineering increasingly requires students to work in multidisciplinary teams. (It should be noted that the ME department is not unique in this regard; indeed, the situation is much the same in all the engineering departments.) The department is encouraged to explore possible ways to relax some graduation requirements and increase flexibility to enable its students to take other engineering and science courses. The challenge, of course, is to maintain a solid grounding in mechanical engineering, while giving students the opportunity to broaden their horizons with other disciplines. (A five-year honors BSME program might be a potential approach but may be politically difficult to implement.)

About half the undergraduate students go on to graduate school here or elsewhere, a few find jobs at large firms, a few transfer to other professions (law, medicine, business), and the rest enter the workforce through small, entrepreneurial firms. Such small firms now collectively out-hire the larger firms.

Graduate Program

The ME graduate program has been ranked by US News & World report as 28th among the 91 ME graduate programs reviewed for 2007 (the College as a whole is ranked 21st out of 93 reviewed). This ranking is more or less the same as in the past two years (the department was 30th in 2006 and 27th in 2005). Approximately 70% of applicants are offered admission, which is a rather high fraction, but includes both MS and PhD applicants. The program is characterized by a large terminal Master's degree program, which accounts for about 55% of all registered graduate students.

The department does well in getting faculty involved in the recruiting process but would benefit from being able to make longer-term commitments of financial support through fellowships, for example, which are lacking. The first group visit day for prospective graduate students was held

by the department in 2006, and it resulted in an increase in acceptances, but the graduate students report that the visit day needs to be more organized. The current graduate students could be better utilized in this activity. In addition to other indicators, recent significant increases in the percentages of women and minorities enrolling are a good sign of a healthy program. The department is pro-active about working with GEM to identify potential candidates (and address deadline problems), and several faculty have participated in GO-MAP workshops.

Terminal MSME students do not receive financial aid in the form of RAs, TAs, or fellowships. Those students who are on the PhD track must complete the MSME first and are eligible for financial support. Most of the PhD students are supported for the majority of their stay in the department, with exceptions primarily being Boeing employees and students who are working part-time in industry while finishing their degrees. The ratio of funded RA positions to TA positions has increased in the past few years, which follows the trend of increased research funding in the department, and is critical for building the PhD program. The department is actively working to obtain additional fellowships for graduate students, and is pursuing funding opportunities to increase the number of RAs. A good example is the department's participation in the recent successful IGERT[†] grant led by a faculty member in Chemical Engineering. Another example is the department's submission of a GAANN[*] proposal to the U.S. Department of Education last fall. Although the department currently commits only one year of support at a time, it has a goal of guaranteeing five years of support for PhD students.

With the exception of the initial start-up period, graduate student mentoring is left to the faculty advisor, and thus can vary in quality. It would be useful to have some department-wide activities to provide richer support to students. Faculty and students seem happy with the current structure of the program with the notable exception of the qualifying exam. The current exam includes a two-hour written math test, a four-hour written test on graduate course material and a one-hour oral exam. Presumably much of this could be assessed in the admissions process and from the students' performance in their graduate courses, so that the exam could be more focused on research potential. The department is not unique in this regard, as a number of other COE departments have qualifying exams of a roughly similar nature. It is recommended that the ME department re-examine its examination process and consider ways to upgrade it to focus on research potential.

The rate of PhD production per faculty member per year is about 0.4. The Dean is encouraging the department to work towards increasing this number to 0.75 PhDs/TTF/year. The review committee discussed this issue at length. While increasing PhD production, to levels more commensurate with highly-ranked ME departments nationwide seems reasonable, the needs of the ME "market" should be kept in sight. What is the demand for PhD's by the department's current and potential employers? It has been stated that increased PhD production increases a department's impact by resulting in more PhD graduates going to other universities as faculty members. However, placing UW ME PhDs as faculty at other, presumably peer or higher-ranked institutions, is not the only measure of impact on the field or society. Tremendous contributions have been made to technology and society at large by individuals holding "only"

[†] IGERT: Integrative Graduate Education and Research

[*] GAANN: Graduate Assistance in Areas of National Need

BS or MS degrees. It should also be kept in mind that the majority of the department's graduates end up with careers in industry, and that industry looks primarily for hires at the MS and BS level. Currently, half of the PhD graduates go to industry and half go initially to academia (of the latter, half are post-docs and many of the faculty positions are in foreign universities). The careers of students after their post-docs are not well tracked, so it is not possible to accurately determine what fraction stays in academia. It is recommended that the department begin tracking its PhD alumni beyond the post-doc phase to get a better sense of the actual proportion who opt for academic careers as compared to industrial careers. Such data would be helpful in determining the appropriate PhD to MS ratio. In any case, the department should carefully study and assess the market for PhD graduates, particularly because the department is considering reducing the emphasis on MS throughput to support the growth of the number of PhDs. An increased emphasis on PhD research will not have a negative impact on the undergraduate program, if it is leveraged to expand undergraduate involvement in research.

The diversity of the graduate student body has been increasing in recent years: in the MS program approximately 14% of students admitted in 2006 were underrepresented minorities and 32% were women, and in the PhD program approximately 11% of students admitted in 2006 were underrepresented minorities and 22% were women. The department is proactively working to increase these numbers to be more representative of the population at large.

Self-sustaining Programs

Until recently the department did not offer stand-alone, self-sustaining programs. It has participated actively in EDGE[†] distance learning course offerings for many years, and graduate students from industry are able to complete the requirements for a non-thesis MSME via this course delivery method. In addition, a small number of PhD graduates have completed their course requirements through EDGE. Participation in EDGE provides the department with external income, but it is relatively modest. In the early fall of 2006, AMTAS,[*] the FAA Center of Excellence (which the department leads), first offered a short course on composite structures and materials through UWEO's EPP (Engineering Professional Programs) office. This offering was successful, and the short course is being repeated this spring. However, it probably will not be managed through EPP due to dissatisfaction with the level of service offered by EPP since the transfer of its operations from the College of Engineering to UWEO. Because AMTAS is managed by ME, the department stands to benefit most from the revenue generated by these short courses.

4. Research

The review committee found that the overall quality of research in the ME department ranges from good to very good. As is the case in most departments, there are some faculty who are engaged in well-funded, groundbreaking research with collaborative interactions, and others who do little or no research, though the latter are few in number (about 15% of the faculty). During

[†] EDGE: Education at a Distance for Growth and Excellence

[*] AMTAS: Advanced Materials in Transport Aircraft Structures

the past five to six years the department's research thrusts have ventured into non-traditional areas that have not normally been associated with the field of mechanical engineering. These new areas include biomechanics, advanced materials and nanotechnology, and quantum systems. Research in some of the traditional areas also continues; these include fluid dynamics and heat transfer, manufacturing and design, controls and systems dynamics, combustion and energy systems, and structural mechanics.

The four historical interest areas (system dynamics, mechanics of materials, energy and fluids, and design and manufacturing) make sense from a curriculum perspective, in that they complement the fundamental areas that provide the basic foundation for mechanical engineering education, but these areas do not reflect the new directions in which the department has been increasingly moving. The new research areas identified above have developed in the department largely because of the realities of external funding. In recent years federal and other funding sources have moved away from supporting the traditional areas of engineering and have directed their funds to new areas such as nanotechnology, biotechnology, and information technology, which are widely acknowledged to be the current "hot" areas for funding. Whether these topics will have long-term staying power remains to be seen, but it would be imprudent to throw all the department's eggs into those baskets. Flexibility and balance are the keys to maintaining strength in traditional areas while embracing new opportunities, something the ME department has been doing over the past few years. The result has been a strong and healthy increase in external funding since 2001, an annual increase that has surpassed that of the College of Engineering, a laudable achievement.

Faculty in the department appear to be innovative in their research, as exemplified by the large number of invention disclosures they have submitted annually in recent years to the Office of Intellectual Property and Technology Transfer (OIPTT). A good example is 2005, when the department filed 92 such disclosures, compared to 325 for the entire College (which is comprised of nine departments and one program). Conversely, this large number of invention disclosures has not yet resulted in a comparable rate of production of U.S. patents. In 2005 only one patent was granted to ME. However, it can take many years to progress from a disclosure to a patent; thus, the jury is still out on whether the department's innovations are truly substantial (it should be kept in mind that innovations don't necessarily always lead to patents but can be manifested as publications in archival journals; indeed many scientific and engineering innovations that have appeared in journals have never been patented). This question should be revisited in five years, at which time the ratio of patents to disclosures will be more easily discernible.

The department prides itself on having many cross-departmental collaborations, but not all of them are as substantive as they should be. A prime example is AMTAS, the FAA Center of Excellence, which the ME department leads (the Director of AMTAS is Mark Tuttle, the department Chair[†]). This Center was announced in December 2003, and funding for it began in September 2004. It differs from the type of Center funded by agencies such as NSF or NIH in that the research to be funded is not selected by the Center leadership at the UW and its partner institutions (WSU and OSU) but by the FAA itself. Thus, AMTAS as a Center is simply an administrative umbrella. While the ME department does, indeed, administer the Center, no ME

[†] The department should consider hiring a full-time director for AMTAS, in order to relieve the Chair from this sizeable administrative burden.

faculty member has yet actually performed research under FAA funding. The bulk (~70%) of the research funds since the inception of the Center has been directed by the FAA to the UW's Department of Aeronautics and Astronautics (where the idea for the Center was originally conceived), and to faculty in the Department of Materials Science and Engineering, as well as occasionally to faculty at OSU and WSU. A small fraction of the FAA funds is allocated to the ME department to cover AMTAS' administrative expenses. In short, AMTAS is a multidisciplinary endeavor for the ME department but the latter's role in it is purely administrative.

Another multidisciplinary research group that the department mentions in its self-study is the Center for Materials and Devices for Information Technology Research (MDITR), an NSF Science and Technology Center, but this endeavor is led by the Department of Chemistry. ME's collaborative role is through one faculty member, who in addition to participating in research through the Center, acts as the UW's local director of diversity in the Center. The department's involvement in the recently-awarded, five-year NSF IGERT grant is as a collaborator, not as its leader (the grant is led by a faculty member in Chemical Engineering). The department also participates in (but does not lead) three other centers in which it has significant research roles, namely, the Center for Nanotechnology, the UW Engineered Biomaterials Center (UWeb), and the Microscale Life Sciences Center.

It should be noted that there are four major multidisciplinary programs which the ME department did establish and continues to lead; they include the Quantum Systems Engineering MURI program, headed by Prof. Joseph Garbini; the Center for Intelligent Materials and Systems (CIMS) and the MURI program on energy harvesting and storage, both headed by Prof. Minoru Taya; and the Center for Computational Biomechanics, headed by David Nuckley. These programs are not only administered by ME, but its faculty are conducting the core research. One research faculty member (Eric Seibel) brings in large amounts of external funding through several grants which do not comprise a center or MURI (he had more than $1.5 million in research expenditures in FY 2006). Not surprisingly, it is research programs such as these which account for the bulk of the department's external support.

Although the Energy/Environment group in ME is currently not strongly funded, the opportunities that loom in this area should be aggressively seized and developed by the ME department. Energy is headed toward a crisis of global proportions. Although government funding has been slow to react, interesting prospects are emerging for direct collaboration with industry, particularly in the areas of renewable energy (biofuels, wind and tidal power, photovoltaics, geothermal power, etc.) and environmental mitigation. In addition, ample opportunities exist for multidisciplinary collaborations with other departments in the College and the University. It is the ME Department that should be taking the lead in this regard but so far has not. The Department of Chemical Engineering has taken the first step by organizing a cross-departmental Energy Seminar that began in spring quarter 2007. Why did ME not think of doing this long ago? Some faculty in ME are frustrated that the department did not follow their strong recommendations to include the energy/environment area during a faculty search two years ago. Despite this perceived setback, the Energy/Environment group should be more proactive in forging and leading novel research partnerships in this area. There is ample existing talent, and it can be augmented through collaborations.

The department made it clear that it is looking to climb the graduate program rankings into the top 20. The metric that seemed to be used for determining excellence in research was repeatedly given as the amount of external funding per faculty; in fact the department's strategic plan quotes $300K/year/faculty as a goal. An assistant professor stated that he needed $1.5 million in research to achieve tenure. Similarly, a senior energy faculty member discussed the turbomachinery candidate from Georgia Tech, noting that "He brings in a million dollars." There seems to be excessive focus on research funding levels, which is a bit shortsighted. If this mindset becomes embedded, it may lead faculty to engage in activities that may bring in large amounts of money but not necessarily increase their prestige or standing in the field. As a realistic example, a faculty member might take on a series of short-term lucrative industry contracts that may not lead to any new ideas or publications. Another example would be a brilliant theoretician who may feel undervalued because his/her research doesn't need much money to be successful. In the long run, it's the ideas and people that come from the department that determine its rank.

Finally, the department's web site and its Strategic Plan are not consistent in the identification of the areas of current and future research. The ME Chair admitted that the website was out of date, and the review committee urged him to have it updated as soon as possible, because it projects an inaccurate picture of the department's research activities and plans. More comments on this issue follow in Section 5 below.

5. Strategic Plan

Background

The Department of Mechanical Engineering has a strategic plan that was first formulated in 1996 and updated in 2006, utilizing standard practices, namely environmental scans and SWOT analysis* resulting in goals and action plans. The strategic plan is reviewed annually. The SWOT analysis resulted in the following:

<u>Strengths</u>

- High demand for the undergraduate Mechanical Engineering program
- Collaborative faculty
- Biomechanics
- Advanced materials and structures
- Quantum systems engineering
- Entrepreneurial faculty

* SWOT: Strengths, Weaknesses, Opportunities, and Threats

Weaknesses

- The Mechanical Engineering building and related infrastructure are not sufficient to meet current and future needs
- Faculty salaries are too low
- Research expenditures are too low

Opportunities

- Development efforts supported by alumni
- Nanotechnologies
- International educational/research activities
- New UW leadership provided closer ties with the Mechanical Engineering department

Threats

- Faculty retention is a challenge because of salaries

The review committee agreed with this analysis, but identified a few additional points, including:

- Strengths: Leadership seminar series
- Weaknesses: ME is not taking a leading role in cross-department initiatives; there is a lack of integration of research faculty; and the exit ratings by students are low
- Opportunities: development efforts can also lead to endowed professorships and fellowships
- Threats: space limitations to growth, and facility impact on morale

The department's SWOT analysis led to the development of specific action plans to address these for the period through 2010-2011, including:

- Increase annual research expenditures to $300K/TTF
- Increase to rank 20 or higher in US New & World Report
- Hire two TTF per year (including a very specific plan for specific research areas and levels)
- Dramatically improve lab and computing facilities
- Update the undergraduate and graduate curricula to ensure modern engineering practice and new research thrusts are properly represented.

Many of the original action items have been addressed or have shown good progress. In addition to the original plan, the annual reviews indicate that the plan has been adjusted to changes in the environmental scan. However, the weaknesses that were identified still exist and present a challenge. In addition, the committee had concerns about the strategic planning process and some of the specific goals identified, as described below.

Recommendations Regarding Process

It would be beneficial to engage participants external to the organization in the strategic planning process. External to the organization is defined here as participation from outside of the University of Washington; e.g., representatives from industry, current or potential "customers," representatives from technical affiliations with interests in education (technical societies, national advisory boards), and academics from higher-ranked institutions. This would ensure that the environmental scan would be far-reaching and allow participants to think in a much broader scope. It would also be more useful to use a subset of the department and include some of the graduate and undergraduate students (both the newer and more experienced students) in the planning process. This would allow for a life cycle process approach that would be more inclusive. If the department is not using a facilitator, it should consider doing so.

The strategic plan needs to reach out beyond five years. Tactical activity planning for one year is good. Five-year strategic planning is good but is still a near-term view. The plan needs to stretch beyond five years to allow for planning and executing large ideas (in the words of *The Harvard Business Review*, "the big, hairy, audacious goals" or BHAG). Even if periodic reviews result in changes and adjustments, the larger ideas often require strategic plans and missions that reach beyond five years.

As mentioned previously, the department also needs to update the "Thrust Areas of Research" matrix to reflect what they currently work on. Once the matrix is updated, there are actions that need to be taken. The first is to identify the three to four key areas where the department wants to focus and grow. In a 4x4 matrix, there are 16 opportunities for major focus areas, but the department should not be identifying work in all 16 areas. It could have three to four major areas with one to two areas that would be the primary areas for focus for the near term, in keeping with the approach on which the department has embarked.

The final matrix should be populated with the current faculty expertise and the current areas of research. This is one way to identify the keys areas of focus that will be developed so that the department can differentiate itself from other departments of Mechanical Engineering at other universities. The matrix would also be used to evaluate the risks, issues, and opportunities for the department and to better position it to present the appropriate directions for research and education. Attention to and use of the matrix will also allow the creation of an appropriate operational plan and organization that promotes the proper execution.

There also needs to be a well-planned communication plan to the department's constituents for the strategic plan and the action plans. All of the constituencies need to understand and support these plans. When asked about the work of the department or the mission and strategies, everyone in the department should be able to explain the strategic plan and how their activities support the plan

The Visiting Committee needs to be either engaged differently or reconstituted. Because the make-up of the Visiting Committee is all from industry, it should serve as an Industry Advisory Board. The membership of this board needs to be evaluated so that participation is active and the membership provides an advantage to the department. Whether or not a separate, strictly

industrial advisory group is kept, the Visiting Committee should include a significant number of senior faculty (preferably Chairs) from other, higher-ranked ME departments at other institutions. For a department of this size, it is feasible and even desirable to support both types of external advisory groups, but the strategic planning needs to involve primarily the Visiting Committee

Recommendations Regarding Goals

The goal of research funding at the level of $300K/year/faculty, in the absence of other indicators of quality, puts too much focus on funding. Clearly, funding is an important input to the process, but what is more important is the output, such as PhD graduate placement, archival publication rate, student/faculty awards, etc. Depending on the type of research, a faculty member may need far more or far less funding to have an impact on his/her field. The statement of this specific goal has left some assistant professors thinking that they need to bring in a total of $1.5M in order to get tenure.

The strategic plan for hiring does not explicitly address retirements, is overly specific, and following it would likely cause the department to miss out on opportunities for hiring star people who might fit in the overall department thrusts in a slightly different way. More importantly, such a specific plan is likely to get in the way of opportunistic hiring of women and minorities. In fact, the department should think seriously about hiring from underrepresented groups as being part of their strategy. Because the diversity climate in the department is positive and there is some minority representation on the faculty already, and because women faculty can be leveraged through the College's ADVANCE program, this set of circumstances could be used to the department's advantage in faculty recruiting.

Another limitation of the faculty hiring approach in the current strategic plan is that there is not a clear indication as to how to prioritize all the areas listed. If all the proposed positions are not provided, which areas are most critical to the department gaining pre-eminence in any research area? The hiring strategy should have a clear prioritization of which areas are to be built up, what sequence to follow, and what contingency plans are in place, should some hires not materialize.

There is little mention of staff in the strategic plan. The description of the process mentions a few staff members that had input, but neither the SWOT nor the goals mention staff. Increases in research funding and the likely move by the College to direct freshman admission into departments will surely impact staff, and improvements to lab and computing facilities could potentially involve expanding and/or providing training to existing staff. How will these changes be handled?

In brief, we recommend that the next strategic planning exercise take better advantage of the Visiting Committee, move beyond measuring research productivity primarily in terms of funding by considering measures of quality, identify a narrower focus for research growth (at least in the short term) but with prioritization of other areas to provide flexibility for opportunistic hires, and consider infrastructure and staff needs associated with growth.

6. Faculty Recruiting

The issue of faculty hiring was touched upon in Section 5 above, but the review committee felt that it was such an important issue to the future of the department that it deserved additional comments in a separate section dedicated to this topic.

The ME department has outlined a very ambitious plan for faculty growth through hiring. This plan calls for a net increase of faculty in the department of two tenure track faculty per year for the next five years. To achieve this net increase in the number of faculty, it is required that on the average more than two faculty per year be brought in to account for retirements and other departures. It should be noted that while the department believed that this aggressive hiring plan had been approved by the Dean, it turned out to not be the case. In the exit interview the Dean stated that the department does not have approval to hire 10 faculty over the next five years and will have to justify each future hire one at a time, as all departments are required to do. Regardless of how many new faculty the department is allowed to hire in the near or longer-term future, there needs to be a very clear and effective strategy for recruitment.

It is clear that faculty recruiting is very competitive on the national scale. The top PhD students and post-docs are usually 'fought' over by premier institutions. This trend will not abate in the future as many schools tie a rise in the rankings to the infusion of young talent. Therefore, an approach for competing in this talent search should be revisited by the department.

The current faculty recruiting process in the department was not completely described in the documentation provided to the site review team. However, in conversations with the faculty, it did seem to be of a cyclical nature that started with the approval of a hiring slot by the Dean. Then an ad was placed, applications were received, sifted and sorted, then a short list was developed. This short list was 18 people long in a recent search. From this list, seven to eight people were brought to campus for in-person interviews. The bulk of the interviewing would then happen in the Winter or Spring quarters.

It is recommended that the department move to a continuous search process in order to be competitive at the national level. Faculty recruiting should become a 12-month process that carries over from one year to the next. The search committee chair should be appointed on a multi-year term, and so should the majority of the committee members. The committee turnover should be on the order of 25-33% annually to maintain institutional memory but also inject new perspectives. Additionally, ads should be written with a balance of targeting a particular set of growth areas but broad enough to capture a stellar candidate that might fall outside the direct scope. All the ME faculty should participate in this 12-month activity by bringing opportunities to the attention of the search committee.

The motivation for this recruiting approach is to properly track and follow high-potential faculty candidates over an extended period of time. Several of the most outstanding junior candidates are known in small circles from when they are still junior graduate students. Relying on "time in the market" rather than "timing the market" will allow the department to be aware of a wider range of excellent personnel opportunities. It will also allow the department to build relationships with people (graduate students, post docs, junior faculty) over a period of time

during which the ME department waits for the right opportunity to get the desired candidate. A promising potential future candidate, possibly only in their 3rd or 4th year of graduate school, can be interviewed early in the Fall quarter while the search committee's load may be fairly light. This would then initiate the cultivation of a relationship with the candidate and possibly catalyze the opportunity for a multidisciplinary hire with another department since the other department would have the opportunity to appraise the candidate in person.

There should be a continued emphasis placed on finding qualified diversity candidates for the ME faculty. It should be noted that we understand two female candidates were made offers recently. That is to be lauded and continued. By moving to a continuous process, it may be possible to find further opportunities to increase faculty diversity. We encourage the department to work with the Dean and Provost to secure support for critical diversity targets of opportunity that emerge during the course of searching for candidates.

There should be a continued emphasis placed on discovering new technical and scientific opportunities through the addition of faculty. New hires will, hopefully, be around for several decades. Therefore, it is important to bring in people with fundamental scientific skills and intellectual agility. These new hires will need to adapt and exploit the changes in technology that are sure to occur over their careers and, moreover, should be the ones that create new technology from basic science. Bringing in people that are solely focused on particular technologies is a risk since the technology could become obsolete over the course of an academic career.

The process of hiring faculty for the sole sake of replacing an existing technical presence in the department (e.g., replacement hires) should be discouraged. Examples of this would be hiring in an area to support curriculum, particularly if the curriculum is popular with undergraduates. Hiring should be focused on bringing in new scientific capability that can result in departmental pre-eminence nationally and internationally. One way to cast a broad net may be to place ads in venues not normally in the scope of ME; for example, in *Science*, *Nature*, etc.

The recruiting process will have additional cost if it is a continuous 12-month activity. This increased cost can be in terms of increased faculty time to contact and track individuals as well as going through additional files. The increased cost can also be in terms of additional visits to campus by faculty candidates. The cost can be partially justified by treating additional interactions with potential candidates as a publicity/visibility tool as well as an evaluation tool. This can spread the cost over multiple departmental functions. Also, it may be possible to use communication technology to do a better and lower cost job of seeing additional candidates. For example, web-casts and web seminars can be used to evaluate and pre-screen short-listed candidates without having them all visit campus.

The department can also benefit from a targeted recruitment plan for specific research faculty skills that can augment the department's research and teaching missions.

7. Concerns

The review committee's concerns, some of which have been expressed already are listed here. They can be generally broken down into four different categories, the physical plant, i.e., the ME Building, department morale, student advising, and miscellaneous concerns.

Physical Plant

The department infrastructure is not aligned with the needs of the program, particularly for research. There is not enough space for expansion; the existing space is not well suited to growth in important research areas (e.g., the inability to install fume hoods); and there are aging building problems (e.g., ventilation and plumbing) that in some cases may be causing an unhealthy environment for students, faculty, and staff. Plans for a new building should be accelerated, but attention to department needs in the interim is also vital. The building infrastructure must be improved in the short-term. Complaints about problems that potentially cause health risks (such as brown drinking water) should be investigated and addressed.

In terms of finding new short-term space, the department recognizes the challenges and is being proactive in identifying possible solutions. However, they could do a bit more. It was the review committee's sense that some old equipment and materiél in the basement could be surplused to free up more space for addressing the needs of researchers or senior design project teams. The University has helped the department by providing space in other buildings, some off campus, but this should not be the main solution. The diaspora of research labs is undesirable. There is a large amount of UW-wide classroom space in the building that could be used to support near-term Department growth.

Factors Impacting Morale

As noted above, the department's morale, overall, is very good. Faculty, staff and students are pleased with the leadership of Prof. Mark Tuttle, and department members are proud of the advances they have made in the past few years. However, there are factors that dampen the enthusiasm and should be addressed in order for the department to move to the next level of excellence. Of course, the run-down state of the building is a major factor. In addition, the fact that faculty salaries are well below those at peer institutions (by nearly 20%) is leading to morale problems, and this concern spans the faculty – it is not limited to a small subgroup. Lastly, the staff feel stretched very thin, although at the same time they are happy to be in the department and very committed to it. In particular, there appears to be no mechanism in place for technical staff to back each other up, so lab or project classes are sometimes canceled if a staff member is on leave due to illness. There are plans to hire another person to help supervise the student machine shop, so this particular problem may be addressed in the near future, but the general problem of tension over being stretched too thin is worth monitoring until the situation improves measurably.

Advising

There appear to be different perceptions related to the student advising staff. The review committee heard some positive comments but mostly complaints from undergraduate students about inadequate access to advising (having to wait two weeks for an appointment), insufficient effort to find answers to questions, and some examples of inappropriate advice that leads to delayed graduation. The committee also heard that some students, in frustration, turn to staff advisors from other departments. From our meeting with the advising staff, a very different picture emerged, i.e., that students usually get to meet with advisors the same day they come in and that advisors receive a lot of positive feedback from the students. Since the undergraduates we met with at lunch were self-selected, some of the mismatch may be due to the biased sample, but the input came from other groups as well (some external), so the issue is worth some attention.

In addition, the advising office probably needs some restructuring, and it will definitely need more staff if the department moves to admit freshmen. Currently there are only 2.5 people on the advising staff, and significant time is devoted to tasks other than advising, such as scheduling, department functions (Centennial, Open House, etc.) and management (in particular the head of advising seems to spend an unusually high fraction of her time on management). Advising staff are responsible for exit surveys, which were supposedly conducted but results were not tabulated, representing a lost opportunity. In addition to increasing staff numbers, it would be useful to look into ways to make some of the advising tasks more efficient. It is also recommended that one staff member be assigned to deal solely with undergraduate students and another to deal solely with graduate students, because the issues surrounding undergraduate and graduate education differ significantly, and one individual cannot be expected to be expert in both areas.

It is also a concern, as noted earlier, that a large percentage of academic advising tasks are handled by department staff members who do not have an engineering background. While the staff are typically better than faculty at being aware of specific requirements, faculty are much better at helping students identify specific subfields that might be a good match to their interest. The department review materials described a mentoring program that gives students the opportunity to associate with a full-time faculty member, but it is not clear that many students are aware of this opportunity and take advantage of it.

Other Concerns

- The Visiting Committee is underutilized. It is currently ostensibly an Industrial Advisory Board, but is being used primarily for curriculum issues. It is certainly appropriate for the Industrial Advisory Board to comment on curriculum, and particularly important to utilize them for senior project opportunities, but this board should also be a resource for the research mission of the department. A separate Visiting Committee composed in part of academic leaders is needed to provide a more long-term perspective on curriculum and research issues, and strategic planning.

- The department has lost 1/3 of its faculty over the past 20 years. We were not able to determine why this happened, since we heard about this late in the process. We understand that the empty lines helped with operating budget shortfalls. The department views this loss as one reason to engage in substantial growth, but this view is not shared by the Dean. This is not to suggest that he is opposed to growing the department. On the contrary, it is the Dean's position that growth should be motivated by plans for the future rather than past history.

- Research faculty are not sufficiently integrated into the department. Some are very happy, but many feel marginalized. The fact that many are located in other buildings or off campus contributes to the problem, but there are several other factors that are easier and more important to address if research faculty are going to achieve the high standards for promotion that we believe the College of Engineering expects. Mentoring junior research faculty should be just as important as mentoring tenure-track faculty. They should be encouraged in attempts to establish some degree of independence from their original sponsor. Their research efforts should be promoted in department PR materials and with graduate students in the same way that tenure-track faculty are. The research faculty gave various compensation numbers for their teaching – such compensation should be equivalent to that of tenure-track faculty of similar rank.

- There is a lot of potential and opportunity for the ME department, but one of its biggest challenges will be for it to break away from the past and move toward the future. Department Chair Mark Tuttle is someone who listens well and apparently makes decisions so as to maximize an objective function consisting of everyone's satisfaction. This approach is rooted in the department's history, as well as in Mark's own management style. For as long as anyone can remember, the department has been highly process-oriented, and has arrived at decisions through consensus. While it can be argued that this approach assures broad buy-in for all decisions, it can significantly slow the decision-making process or grind it to a halt altogether, particularly in a department of this size. Mark's continued application of this paradigm ties things a bit too much to the past, and tends to circumvent his having to make difficult decisions on his own. However, the flip side to the consensual, process-oriented approach is that everyone feels that their input is valued, and therefore the morale goes up a bit (but only when progress is positive). However, bringing a department to a higher level of excellence frequently necessitates decisions that are not agreed upon by all who might be affected. An effective leader with vision knows when an executive decision must trump consensus for the good of the department. We encourage Mark to be more proactive in this regard.

8. Recommendations

In the previous sections of this report a variety of recommendations, both general and specific have already been made. In this section are summarized the main points that the review committee wishes to make. Most have been stated already in the preceding text. This section is organized into two general types of recommendation, those to the department, and those to the College of Engineering and the University.

The primary recommendation to the department, the College, and the University is that the department's undergraduate and graduate programs be continued.

Recommendations to the Department

General Recommendations

1. Continue all degree programs in Mechanical Engineering based on the department's performance and potential, and through implementation of the recommendations of this report.

2. Focus and prioritize the department's strategic plan, as this is vital to the development of the department and continuing support from the College.
    A. Extend strategic plan beyond five years.
    B. Add external participants to contribute to strategic plan.
    C. Identify fewer focus areas; three to four major areas with one to two areas that would be the primary areas for focus in the near term.
    D. Prioritize target areas for hires and develop plans if some hires do not materialize.
    E. Do not choose fields to emphasize based only on present faculty interests; emphasize discovering new technical and scientific areas through new faculty.
    F. Stress fields that have a strong future (e.g., energy, biomechanical devices, advanced materials).
    G. Establish continuous search for diversity candidates for faculty.
    H. Guard against bias that favors research funding over scholarship and teaching.
    I. Establish criteria and actions to evaluate implementation of the strategic plan.

3. Add academic leaders to Visiting Committee and change the current Visiting Committee to an Industrial Advisory Board; involve the Visiting Committee in strategic planning and research guidance, not only curriculum reform.

4. Add staff to cope with increased administrative pressures generated by admission of freshmen and increases in research funding

5. Benchmark approximately three other institutions and track progress relative to them. As an example, pay attention to things like where graduates go after they graduate. Does the department produce PhDs who go to institutions as good as the UW?

Academic Recommendations

1. Make the strongest possible case for recruitment of new faculty.
2. Establish a standing committee for continuous faculty recruiting.
3. Admit freshmen into the department when additional resources and space are made available.
4. Explore possible ways to relax some graduation requirements and increase flexibility to enable students to take other engineering and science courses.
5. Improve capstone projects, possibly with more or different industry involvement, and consider student complaints that pre-requisites for capstone projects are not taught each quarter.
6. Compete strongly for graduate students, especially students from the Northwest quadrant of the U.S., where the department has a particular advantage.
7. Support PhD growth with more multi-year research funding, e.g., NSF IGERTs, provide support guarantee for up to five years.
8. Utilize instructional lab space effectively (eliminate duplication of labs and facilities between departments to extent possible; throw out unused equipment and other unnecessary material to free up space).
9. Consider joint-listing some courses and sharing some teaching labs with other departments.
10. Encourage/require/reward participation in FE exams.
11. Improve the advising office.
    A. Reduce advising errors that force students to take five years to earn the BSME degree.
    B. Make sure students know about faculty and staff advisors, services, and procedures.
    C. Assign separate advisors to the undergraduate and graduate programs.
    D. Allot more time for advising during drop periods.
    E. Involve more faculty in advising (leads to better student experience and alumni support).
12. Develop a plan to improve ratings on Exit Questionnaires for MS and PhD students, and analyze and track the results.
13. Scrutinize the qualifying examination process and consider changing it to focus on research potential.

Research Recommendations

1. Continue trend toward more research funding and larger roles in collaborative programs, but do not lose sight of the important indicators of research productivity and success: publications, conference participation, citations, supervision of graduate students, impact, etc., i.e., research quality.

2. Seize research opportunities and forge and lead novel research partnerships in the Energy/Environment area.

3. Increase mentoring of research faculty and ensure their compensation for teaching is equivalent to that of tenure-track faculty of similar rank. Research faculty must be made to truly feel they are valued members of the department.

4. Provide sufficient staff supported by research funds, e.g., instrument maker, fiscal specialists, etc., as appropriate, to support research programs.

5. Consider hiring full-time director for AMTAS to remove administrative burden from Chair.

Recommendations to the College and University

1. Work with the ME department to advance its Strategic Plan.

2. Accelerate replacement of the ME Building because it is inadequate for high quality instruction, research, and recruiting/retention, and take corrective action on potential health issues.

3. Help find space in the interim for offices and labs on or off campus for growing research needs.

4. Provide resources adequate for the admission and education of freshmen (advising staff, faculty, classrooms, labs, offices).

5. Provide more resources to support increasing the rate of PhD/TTF production.

6. Consider diversity recruitment partnering between College/University and ME department.

7. Increase faculty salaries to eliminate the serious gap with ME departments in peer institutions.