University of Colorado **Boulder**

2018 Program Review

Mechanical Engineering

Academic Review and Planning Advisory Committee Report

Approved

04/23/2019

Provost and Executive Vice Chancellor for Academic Affairs. | Date

Contents

Process Overview

The Academic Review and Planning Advisory Committee (ARPAC) conducts and writes the final reviews of all Boulder campus academic units. The Department of Mechanical Engineering (ME) completed a self-study in the fall of 2017. An internal review committee completed an assessment in February 2018 and described the strengths of the department and the challenges that it faces. While the internal reviewers found the self-study to be accurate, it ultimately provided 26 recommendations for self-study changes. The self-study was substantially revised to reflect the internal reviewers' recommendations. An external review committee composed of two experts from institutions outside of Colorado met with faculty and staff over April 9-10, 2018, ultimately providing a report recommending various improvements in department processes. Internal and external reviewer comments and recommendations are cited at points throughout this report. This public document reflects the assessment of and recommendations for the Department of Mechanical Engineering as approved by ARPAC.

Academic Review and Planning Advisory Committee (ARPAC)

Academic Year 2018-19 Voting Members

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Unit Overview

The campus's standardized description of the unit is available on the website of the Office of Data Analytics (ODA) at https://www.colorado.edu/oda/institutional-research/institutional-level-data/information-department/academic-review-and-planning. ODA updates the profile annually in the fall semester. This report cites data posted in October 2017, reflecting the state of the Department of Mechanical Engineering (MCEN) as of the academic year (AY) 2016-2017.

MCEN is nationally recognized with award-winning faculty who occupy positions as fellows in national research societies, raise eight-figure annual grant revenue, and start companies that implement their research. Since the 2011 ARPAC review, undergraduate enrollment has nearly doubled. This increase, however, has thrown the department's student-faculty ratio out of sync with the target set by the Accreditation Board for Engineering and Technology (ABET). In spite of enrollment pressures, MCEN has found new ways to engage students, including by employing innovative educational facilities like the Idea Forge, a design and fabrication facility. However, many teaching spaces are dated and cramped. Rapid growth has led the department to spread over disparate locations, which limits cohesion. The next five years promise even higher enrollments and no clear path ahead for increased, improved, updated, or contiguous spaces.

Personnel and Governance

According to department figures (that differ from Office of Data Analytics [ODA] figures), MCEN has a contingent of 38 tenured and tenure-track (TTT) faculty members (34.5 full time equivalent FTE), including 12 (9.5 FTE) professors, 13 (12.5 FTE) associate professors, and 13 (12.5 FTE) assistant professors. Additionally, the department employs three research professors, five instructors, one senior instructor (0.5 FTE), one

lecturer, one scholar-in-residence, and five Colorado Mesa University (CMU) campus instructors. Fourteen staff members support department operations.

The department approved bylaws in 2001 and updated these in 2012 to define who qualifies as voting faculty members. College of Engineering and Applied Science (CEAS) policy, reflecting University of Colorado Board of Regents policy, governs promotion and tenure procedures. A five-member personnel committee oversees MCEN unit-level reviews. The department has various standing committees whose decisions can be appealed to the department chair. Further appeals are sent to the personnel committee. The personnel committee also hears appeals concerning merit reviews and salary equity. Department bylaws do not include guidelines for annual merit review except to refer to the college policy.

Research and Scholarship

MCEN faculty members have expertise that crosses at least four mechanical engineering fields: biomedical, energy, environmental links to energy, and materials innovation. The faculty have won major international awards, like the Moore Inventor Fellowship, the Packard Fellowship, the National Science Foundation (NSF) CAREER Award, and the NSF Early Career Award. MCEN faculty members hold fellowships in a number of professional societies, including the American Physical Society and the American Society of Mechanical Engineers.

A number of federal agencies have awarded MCEN faculty grants in recent years, comprising over $10 million per year. Research spending exceeded $13 million in FY 2017.

MCEN faculty members have started companies based on their research in the areas of medical instruments, sensors, cooling,

and batteries. Among these, Precision Biopsy, a company started in 2008 by an MCEN faculty member and a colleague from the Anschutz Medical Campus, has received $30 million in funding and has gained US Food and Drug Administration approval to begin Phase B trials of a needle technology.

The department plans to apply to become a National Science Foundation (NSF) Engineering Research Center of Excellence in Nano Materials. MCEN also plans to expand its research expertise into soft robotics, imaging complex media, and quantum technologies. In line with these goals, the department would like to increase its faculty contingent by 15 tenure stream members over the next five years. While this expansion is large, anything less will make it difficult to regain the ratio of TTT faculty to undergraduate students MCEN had prior to its recent expansion.

Undergraduate Education

MCEN offers a BS in mechanical engineering with tracks in biomedical and environmental engineering. Students may earn the BS in conjunction with an MS. In AY 2016-2017, the department enrolled 1,007 undergraduate majors and awarded 252 BS degrees, numbers that have approximately doubled over the last five years and are expected to rise further. Of the AY 2016-2017 graduates, 6% earned a concurrent MS degree and 15% chose a track. These numbers include 24 graduates of the CU Boulder–Colorado Mesa University (CMU) joint mechanical engineering program (of 61 enrolled students there). The CMU students typically spend all four years in Grand Junction, with the first two years taught by CMU faculty and the last two years taught primarily by CU Boulder faculty.

MCEN retention, graduation, and placement rates are all high. According to multi-year tracking data presented in the self-study, 90% of the department's first-year students remained

ME majors in their second year, 85% remained so in their third year, and 79% graduated within six years with the ME BS degree. The department's retention rates are higher than those associated with any other CEAS department. Impressively, the strong retention numbers are nearly identical for men and women, and are CEAS-best for men, women, and underrepresented minorities. The average time to graduation is 4.33 years, and the job placement rate is 90% within six months of graduation. Less encouragingly, the student body is composed of only 16% individuals who identify as women and only 16% who identify as members of underrepresented minorities.

In AY 2016-2017, tenure stream faculty members taught 38% of MCEN student credit hours (SCH), instructors taught 49%, and temporary faculty appointees the remaining 13%. In spite of the substantially greater population of tenure stream faculty versus instructors and adjuncts, the TTT faculty members typically teach three or fewer courses per year, whereas instructors typically teach five courses.

The BS program emphasizes design from year one to four. Freshman are assigned design projects and a course in computer-aided design (CAD), juniors take a class in component design and seniors are required to take a two-semester capstone design course. Apart from MCEN-assigned Engineering Center, Fleming, and Roser ATLAS classrooms, the department depends on shared and/or centrally scheduled instructional facilities, including the Idea Forge, that features a 12,000 square foot machine shop, and the Instructional Teaching and Learning Laboratory (ITLL), a 34,400 square foot lab space.

Limitations define MCEN instructional spaces and surging enrollments intensify the shortfalls. As an example, the self-study mentions a CAD facility that department students depend on for projects but that CAD lecturers employ eight hours per day, two days per week. This leaves only three weekdays open for other uses. Worse, the self-study describes the space as suboptimal: “it is too small, poorly lit, run down, and the chairs are semi-functional. Computers are outdated and slow, and neither the hardware nor the network are optimized for engineering software needs.”

Graduate Education

The department offers a professional MS, a thesis MS, and a PhD. The doctoral program averages 23 annual admissions; the MS typically 34. In AY 2016-2017, MCEN awarded 45 MS as terminal degrees and nine as a step toward the PhD. That year, the department awarded 14 PhDs. MCEN does not typically track graduate retention, but the self-study claims that it is usually high. Over the last four academic years, the department awarded over 60 graduate degrees—not counting those awarded as a step to the PhD—which is consistent with high retention.

MCEN graduate students typically find private or public sector employment, including with research institutes like the National Renewable Energy Lab (NREL) and the National Center for Atmospheric Research (NCAR). The department does not keep placement data for its graduate students.

A September 2017 climate survey addressed to MCEN graduate students holding appointments found the students generally satisfied with the department. Of 131 students queried, 83 responded. Of these, only two respondents said that they “disagreed” or “strongly disagreed” that they were treated with respect by their advisors. Breaking down

perceptions of climate by specific population groups four "disagreed" or "strongly disagreed" that climate was generally positive for women, five for students of color, one for students of different sexual orientations, five for international students, six for students of different political affiliations, and one for students of different religious views. Some of these numbers are high. Moreover, when asked whether one or more MCEN faculty members humiliate or intimidate students, 20 out of 83 agreed.

Space/physical infrastructure

MCEN has space assignments in the Engineering Center, the Sustainability, Energy and Environment Community (SEEC) building, and in Fleming. These spaces are disparate: Fleming requires a ten-minute walk from the Engineering Center, and SEEC a thirty-minute walk in another direction. The department's combined space allocation totals 66,980 square feet, not counting the shared Idea Forge and Integrated Teaching and Learning Lab. The outlay includes 42,644 square feet devoted to research labs; the department uses the remainder for offices and student projects.

With student enrollments and faculty member numbers up substantially since the last review, the current space allocation has not kept up. Lab accomodations for the newest faculty members fall outside of MCEN-assigned Engineering Center, SEEC, and Fleming spaces. The department's common facilities, like kitchens and the mailroom, have not grown at all. MCEN has initiated a space review and expresses hope that it can use space more efficiently, but if growth continues, improved efficiencies alone will not address the shortfall. Furthermore, department cohesion suffers from the far-flung distribution of faculty members.

The self-study notes the excellence of a number of shared facilities, like the Idea Forge and the ITLL. These spaces provide students with useful engineering training. Unfortunately, the capacity of these spaces has not kept up with undergraduate enrollment growth. CEAS should either build more shared labs or allocate MCEN more time in them. The department does not favor the latter option. Few classrooms allow the department to achieve the standard set by the Accreditation Board for Engineering and Technology (ABET) of 20 square foot per student, a shortfall noted by ABET during a recent site visit. The Chevron Design Studio illustrates the pressing space deficit. The studio houses the senior capstone class. As is, the Chevron space can only accomodate a 245 student enrollment. That translates into only 13 square feet per student. Consequently, students' senior capstone projects spill into the hallway or must be housed in other campus spaces or at company sponsor locations around Boulder.

To regain a student/faculty square footage allocation comparable to just five years ago, MCEN estimates that it requires a doubling of space. Additionally, space quality figures into the need. Classrooms with outdated or broken equipment are all too common.

Inclusive Excellence

White men have historically outnumbered other populations in mechanical egineering, including at CU Boulder. As previously noted, among MCEN undergraduates, 16% identify as women and 16% as a member of an underrepresented minority group. These numbers match those at other institutions, and represent an improvement since AY 2011-2012 when14% of undergraduates identified as women and 9% as belonging to an underrepresented minority group. The unit has not created or submitted an inclusive excellence narrative.

MCEN faculty members collaborate with the BOLD Center to build community among women and underrepresented minorities. MCEN faculty members also have a history supporting the Engineering Goldshirt Program, which provides promising students whose high school educations did not adequately prepare them for the rigors of a college engineering degree an extra year of college. Goldshirt Program students spend the extra year working through gateway courses, but are admitted directly to the College of Engineering and Applied Science. The program started in 2009 and in the decade since, CEAS has admitted 331 Goldshirts. Currently, the program has 163 participants. Fifty of the Goldshirt students have completed their engineering degrees and 12 have completed non-engineering degrees. Engineering colleges at the University of Washington and University of Illinois have looked to the Goldshirt Program as a model.

A 79% increase since 2011 in the fraction of students identifying as belonging to an underrepresented minority population stands as a measure of the Goldshirt Program's success. The number morevover under-states actual growth, given the near doubling of MCEN undergraduate students since then. The CEAS dean has a stated goal of 50% undergraduate enrollment by women. While MCEN has made efforts toward that goal, its growth of women enrollees lags behind growth among historically underrepresented minority groups.

Among MCEN graduate students, enrollments for women and members of historically underrepresented minority groups account for 20% and 9%, respectively, as opposed to 18% and 10% five years ago. Among MCEN tenure stream faculty, 22% identify as women, which is well ahead of the national average of 13%. Only 3% identify as being a member of an underrepresented minority population.

The department's graduate student diversity efforts have lagged behind the success of those directed at undergraduates. These efforts have focused on increasing recruitment-visit invitations directed at admitted new students from underrepresented populations, including women, who have not yet accepted their admission offers. While many women applicants accept the department's visit invitations, these recruitment efforts have not translated into increased enrollments. The self-study claims that this is due to strong competition from peer mechanical engineering departments.

The internal reviewers note that women faculty and staff members see substantial biases within the department. How those biases might manifest is addressed more fully in the section on unit climate below. Before moving into that discussion, it is worth mentioning here that MCEN women faculty identify an office and laboratory space allocation bias. Relative to other issues like non-diverse hiring and low women student enrollments, space allocations would appear to be readily addressable. That it is seen as a problem by women faculty members suggests a deeper inclusion problem.

Climate

Over the last five years, the MCEN climate has undergone a transformation. Departmental turmoil taking place at the time of the last ARPAC report culminated in the department chair's termination. An external chair stepped in for one year to help revamp the department. An external chair stepped in for one year to help revamp the department, including to undertake a planning/visioning effort and to form the Mechanical Engineering Strategic Advisory Board (MESAB) and to task it with continuing planning/visioning work. In spite of these steps, substantial climate issues persist. The department held a day-long retreat in January 2018 that concluded that proper vision implementation, including concrete steps needed to improve

the climate, would require more faculty and staff time explicitly devoted to such work.

ARPAC staff conducted climate surveys in September 2017 addressed to MCEN faculty and staff members and graduate students holding appointments. Of the faculty members surveyed, 77% responded, as did 82% of staff members and 58% of the graduate students. Surveyed faculty included those located at CU Boulder and those employed by the CMU partnership program.

The surveys returned some positive climate assessments, but also identified serious problems. Most importantly, 50% of faculty participants responded “agreed” to the prompt that one or more faculty members say things that humiliate or intimidate other faculty members. Given that only 20% of those addressed did not respond to the survey, this measure suggests a significant pattern. Staff (at a rate of 25%) and graduate students (20%) likewise “agreed.” Furthermore, 17.5% of faculty “disagree” or “strongly disagree” that the social and professional climate is generally positive for faculty. When asked if faculty incivility disrupts the department’s functioning, 30% of MCEN faculty members “agreed.”

The surveys do not appear to suggest that faculty member perceptions of hostility show the hostility targeted at particular groups. Of the 40 faculty survey respondents, three viewed the climate as negative for women, two for faculty of color, zero for faculty of differing sexual orientation, three for faculty of differing political affiliation, and one for faculty of differing religious views. The survey does not clarify whether the small number of negative responses stem from the same three people or are scattered among the whole faculty. While any rate above zero is too large, these rates are fairly small. The surveys

therefore suggest that a number of department faculty members indiscriminately generate incivility.

Perspectives gained at other review phases, including during the self-study, the internal review, and the external review, offer additional perspectives on climate and sometimes sharply differing views. Women faculty in particular seem to express their concerns more fully to outsiders, suggesting that when the faculty members feel freer to discuss climate, they identify more serious problems. This might indicate that some faculty members feel intimidated by other department members. The internal reviewers remarked on the polarization, pointing to the historic turmoil discussed above. All of this is to say that the intimidation that is clear in the climate surveys is also clear in what some faculty members say to internal and external interviewers. It is also clear that the equal-opportunity hostility implied by the climate surveys may not tell the whole story.

The polarization of climate perspectives appears to also encompass perceptions of the treatment of women undergraduates. The internal reviewers report that MCEN women faculty members believe that gender biases toward women undergraduates persist and that they may not be fixable by the department alone. Several suggest bringing in professional organizations and outside gender issue expert to help teach professional behavior in teams. They also believe that an undergraduate climate survey would underscore the scope and size of the problem and help the department address it.

The internal and external reviewers identified a pattern of mistrust directed at college administrators. MCEN TTT faculty members, instructors, and staff all reported conflict between the department and CEAS leaders. The internal reviewers

describe the conflict as encompassing “both day-to-day business and long-range planning.” They further note that “there is a perception that the college is unsupportive and in some cases is actively working against the department…Specific members of the dean’s office are perceived as obstructionist.” As an example, the external reviewers found that the department chair recommended raises for mid-career faculty but that the dean denied these, though this may no longer be the practice under current CEAS leadership. Both the internal and external reviewers report that MCEN faculty members would like a strong chair who can advocate for the department and engage the dean’s office effectively. Many of the faculty members expressed satisfaction with the current chair and concern about what might happen when a new chair takes over.

The external reviewers describe a culture in which some faculty members perceive department service and teaching work allocations as unfairly distributed. They cite a pattern of department leadership obligations falling to associate professors, for one, and a pattern of the department’s shielding poor teachers from instructing students in large or required courses.

The role of instructors also measures as a climate concern for some tenure stream faculty members. The internal reviewers identified a tenured/tenure track faculty member dislike of instructor power in decision-making, especially voting rights for TTT line hiring.

Budget

The department does not fully account for FY 2016 expenditures in its self-study, but provides a breakdown by category. Spending from research grants and contracts totaled $13.6 million, and has averaged over $10 million for the last

three years. Faculty, staff, and teaching assistant salaries, stipends, and tuition remission totaled $5.4 million, with approximately $4.6 million devoted to salaries. The college provides funding for renovations and two-thirds of faculty start-up packages. Indirect cost recovery (ICR) totaled $470 thousand in FY 2016. Faculty members use most of this money to buy down their teaching loads, and department revenue from these buy-downs totaled $362,000. The department devotes the remaining ICR funds to travel, cost shares, and project development. The department also uses ICR revenue for start-up packages and lecturer/adjunct teaching lines. In FY 2016, revenue from the professional MS program totaled $500,000. That year program fee revenue totaled $190,000, though these fees have now been eliminated and replaced with campus allocations. FY 2016 gift revenue totaled approximately $250,000.

Past Reviews

ARPAC last reviewed the Department of Mechanical Engineering in 2011. The review committee then advised the department to develop long-term relationships with graduates and to strengthen ties to industry and to local federal research groups like the National Renewable Energy Laboratory (NREL). While the 2018 self-study does not discuss in detail what attempts the department has made to deepen such ties, it does describe a serious outreach program to graduates. In 2011, ARPAC also advised MCEN to develop its strategic plan, and it has done so. The department treats the plan as a living document that requires routine evaluation and revision. MCEN has recently begun to work on more serious implementation efforts. ARPAC also advised the department to bring its bylaws into alignment with campus policy describing instructor rights and responsibilities. The self-study does not discuss whether this happened, but the concerns of TTT faculty that the department has gone too far in extending instructor voting rights indicates that the department made changes in this regard.

Campus Context

For any engineering college, mechanical engineering functions as a core disciplinary focus. CU Boulder's program is no less critical, and with an increased enrollment to over 1,000 undergraduates it represents a growing campus presence. The faculty publish well and have developed innovative curricula that place students well.

MCEN has a long tradition of interdisciplinary work. Many of the companies founded by MCEN faculty members are jointly run with faculty members from other University of Colorado units. CEAS recently set up a funding program that provides seed grants for six competitively selected interdisciplinary themes. MCEN faculty members direct two of the six themes, and the remaining four rely on MCEN faculty member participation.

MCEN offers courses co-taught with faculty members from other disciplines, such as Flow Visualization, in which mixed teams of engineering and fine arts students undertake projects. MCEN faculty members help to facilitate interdisciplinary programs, such as Materials Science and Engineering, Environmental Engineering, and IQ Biology. Some department faculty members hold joint appointments with the ATLAS Institute, Physics, Chemistry, Integrated Physiology, and Chemical and Biochemical Engineering, as well as with the School of Public Health and the School of Medicine at the Denver Anschutz Medical Campus.

Additionally, the MCEN Strategic Action Committee advocates for improved college and campus-wide interdisciplinary studies policies and programs.

Disciplinary Context

As previously described, the Department of Mechanical Engineering employs a vibrant group of researchers with strong, federally-funded agendas in biomedical engineering, energy engineering, materials innovation, and environmental links to energy. MCEN faculty members have won major international awards and have been named as fellows of national professional societies. The department aims to be a “top 10” mechanical engineering department.

MCEN faculty members have have undertaken collaborations with colleagues at peer mechanical engineering departments, with federal agency employees, and with private industry representatives, including in such areas as medical instruments, sensors, cooling, and batteries. This work has resulted in companies and other innovative enterprises such as the Membrane Science, Engineering, and Technology (MAST) Center that brings together researchers from CU, the New Jersey Institute of Technology, the University of Arkansas, among other institutions, to provide “effective solutions to real industrial problems through cutting edge academic research.”

MCEN faculty are also involved in discipline-based education research, such as the NSF funded “Understanding the Formation of Sociotechnical Thinking in Engineering Education” project.

Analysis

The Department of Mechanical Engineering faces a space and growth challenge that will require campus investment to resolve. MCEN laudably aims to continue to expand its undergraduate program to meet student demand. The department has made great strides in enrolling students from underrepresented populations, MCEN students have a high retention rate, and the students place well after graduation. Students have responded in striking and welcome ways but their increased numbers will require more faculty and all of the space that faculty need to teach and do research. It is incumbent on the campus administration to accomodate the department's space needs. Added space would ideally be contiguous and up-to-date. Many of the department's existing classroom facilities require renovation.

The department also faces an administration and culture challenge. The department has already made serious efforts to revamp its culture. In many ways these efforts have succeeded, but there is still a long way to go. Three climate issues are particularly concerning: (1) a subset of faculty who can be intimidating or hostile, (2) a perceived conflict between the dean's office and the department which the external reviewers associate with difficulty in retaining mid-career faculty, and (3) insufficient progress in advancing women, whether as undergraduate as graduate students, or as faculty members.

Strategic Vision

The department has made progress on its strategic vision. A temporary external chair initiated a strategic visioning process in 2014. That step included tasking a committee to complete an analysis and to develop a vision. The resulting vision document stated that "in four years, the CU ME department will be (i) known for high impact research, (ii) a national engineering leader in project-based education, (iii) a national ME leader in inclusive excellence, and (iv) have an emphasis on engaged

scholarship, innovative and entrepreneurial spirit, and a collaborative community that includes alumni." The department implemented a strategy to advance its vision goals that included 14 actionable elements. The department amends the strategic planning document twice annually.[1]

The department's strategic vision goals have so far achieved a mixed success. MCEN can count the production of high-impact research and an exceptional project-based curriculum supported by well-designed spaces as successes. These strengths were present before the vision was implemented, and further progress will require campus infrastructure investments. Meanwhile, the department's work toward inclusive excellence remains incomplete. ARPAC notes that not one of the MCEN 14 action items address inclusive excellence except as relates to hiring. Action on these 14 tasks cannot be expected to lead to an improved climate for women, students, or mid-career faculty. If inclusive excellence is indeed a core strategy goal, then the strategy should involve tactics that advance that goal. ARPAC recommends adding action items to the strategic vision document that specifically address inclusive excellence and department climate improvement.

Inclusive Excellence and Climate

A successful strategy to address the department's inclusive excellence and climate concerns will require resolving multiple concurrent challenges, including:

1. A perceived lack of support – and sometimes outright obstruction – from the dean's office. The department should try to find the reasons for this perception. Part of the conflict might center on advising, control of which was recently moved from MCEN to the college. If this is an important

[1] The ERC report asserts that the department lacks a strategic vision. It is not clear where this opinion arose.

source of tension, the college should attempt to explain its reasoning and show that MCEN will not be substantially harmed by the change.

2. Mid-career MCEN faculty members report that the department unfairly distributes teaching and service work. The perception is that full professors avoid department service, leaving it to associate professors. Further, complaints that the department assigns poor teachers easier class assignments leaves good teachers feeling punished. A perception that the department undermines competence has had the perverse consequence of disincentivizing good behavior and eroding morale.

    a. Because it is not uncommon for academic units to assign poor teachers easier classes, it is difficult to recommend a change in assignment practices. However, ARPAC suggests that the department consider offering those given difficult teaching assignments additional teaching credit. This way, the best teachers might profit more from their skills. Given that faculty members already buy down their course loads, this change might result in better teachers retaining more of their indirect cost recovery (ICR) money.

    b. The perception that full professors do not contribute sufficiently to service duties may be only partly accurate. Often it can be difficult for early- and mid-career faculty to see the breadth of service that the university requires beyond what the department asks. A lack of awareness of the service work done by full professors at the campus level might contribute to a perception of shirking department-level duties. ARPAC recommends

that the unit track and make known all faculty member service and teaching assignments. This list may include an accounting (whether subjective or objective) of service assignment time commitments. If this step still leaves service equity concerns unresolved, then ARPAC recommends that the department chair refocus service obligations toward full professors. Given other climate issues, it is possible that it would not be wise to assign certain service assignments to some senior faculty members. As with the dynamics animating teaching assignments, the department must not allow poor performers to avoid work. Rather, ARPAC recommends that MCEN take steps to educate poorly performing faculty members about workplace etiquette before assigning them serious service roles.

3. Reports from faculty members and students that a subset of the faculty create an intimidating or hostile environment must be addressed. It is possible that those identified as eroding workplace civility lack an awareness of their behavior and its consequences. It is also possible that those who feel intimidated fail to speak up. ARPAC encourages an open line to the department chair through which faculty and staff members, and students can relay concerns about hostility. The department chair should compile complaints to establish patterns. Faculty members who are found to repeatedly induce complaints should be educated about the perceptions of their behavior and ways to change. If repeat offenders are aware of the way they are perceived and continue to behave inappropriately, the issue should be referred to the dean, who can take escalated action, including reassigning a faculty member away from the department.

4. Finally, a gender divide informs perceptions within the department over how men and women are treated at the student and faculty levels. The dynamics of this divide include:

    a. Women faculty members see substantial hiring biases;
    b. The internal reviewers also identified perceptions of bias among women faculty members in the allocation of office and laboratory spaces. If these perceptions are accurate, then ARPAC views this as an immediate priority. Misallocated space is an easy problem to solve and its resolution a basic indicator of fairness. If misperceptions inform space allocation judgments, then the department should investigate the origin of those misperceptions. It also must be assumed that a perceived space allocation bias serves as a leading indicator of more serious problems. The fact that the department self-study does not mention the space bias perception might suggest that a hostile climate prevents some women faculty members from communicating honestly with the department chair and men faculty members. The department's health hinges on nurturing honest communication. A resolution of the problems that contribute to feelings of hostility will go far to uncover and resolve problems with inclusion as well.
    c. Women faculty members also see gender biases directed toward women undergraduates. Fixing this problem from within the department seems unlikely. ARPAC suggests that the department consider bringing in professional organizations and outside gender issue experts to help teach professional behavior in teams. ARPAC also suggests that the department use undergraduate climate surveys to address these issues.

Undergraduate Education

As already discussed, the mechanical engineering undergraduate curriculum is in excellent shape. That said, the department faces urgent concerns over women student enrollments and a lack of teaching space. Taking on the latter challenge first, the department has minimal leeway to reformulate its teaching space allocation, nothing approaching what it would take to address the shortfall. Nevertheless, ARPAC recommends that the department consider scheduling courses in unused hours and adding sections in order to relieve some constraints. However, this step will not go far enough. Hallway overflow from required courses, a lack of resources such as up-to-date CAD equipment, and students working on projects at off-campus locations speak to the urgency of the problem. ARPAC asks college and campus administrators to find MCEN additional classrooms and funds to renovate existing teaching spaces.

ARPAC urges MCEN to continue its efforts to attract women students. Progress on 4.c above may be sufficient. If not, then increasing outreach to women in high schools and community colleges may be advisable. The strategic plan should include specific action items to grow MCEN women enrollments.

The MCEN Strategic Action Committee describes three changes to the undergraduate curriculum to improve interdisciplinary studies, including (1) enhancing students' exposures to computational methods via computational modules in core courses, co-created with faculty in computer science; (2) encouraging students to take advantage of co-curricular opportunities on campus; and (3) increasing the number of speakers from other disciplines in MCEN classes. ARPAC commends these initiatives and suggests implementing them.

Graduate Education

The MCEN graduate program appears to be in great shape. Evidence from the review shows that students are mostly satisfied, including with the department's placement record. ARPAC recommends that the unit continue the professional MS track's expansion. The department could leverage funds generated by the track to improve educational facilities like the CAD lab, increase new hire start-up funds, and add/improve inclusive excellence programs.

The external reviewers note that the department's PhD program is small by national standards. ARPAC recommends expanding the size of the PhD program, consistent with demand for graduates from industry and academia. Here, too, funds generated from an expanded professional MS track could support PhD student stipends. ARPAC also suggests that the program consider using funds for signing bonuses or other inducements like paid childcare to attract and retain a diverse graduate student body. ARPAC notes that CEAS has already piloted a child care funding program.

Recommendations from the MCEN Strategic Action Committee include two changes to the graduate curriculum to improve interdisciplinary studies. These encompass encouraging mechanical engineering graduate students to (1) undertake coursework outside MCEN and (2) write a thesis chapter on the societal impacts, policy implications, or educational aspects of their research. ARPAC commends these initiatives and suggests implementing them.

Space and Infrastructure

MCEN faces a severe space shortage. The unit is spread across eight areas in three facilities that are as far as a forty-minute walk apart. It is a formula that works against even the best efforts to improve unit cohesion and communication. A world-class faculty that has insufficient room to teach and

research, new hires that occupy labs separate from their colleagues, and basic facilities like kitchens that have not increased in size despite a near-doubling of the department's enrollment, all speak to the growing crises. ARPAC urges the unit to do whatever it can do to use its assigned spaces efficiently and to raise revenues to improve spaces, such as from the professional MS program, but this is not enough. ARPAC urges college and campus administrators to prioritize funding to develop new spaces, or to repurpose existing spaces for MCEN. The crisis facing MCEN also presents a strong case for waiving the campus building and renovations moratorium. If the expectation is for MCEN to continue to grow its undergraduate program, more must be done to accommodate the faculty complement required to teach the new students as well as to address what this means for growing numbers of PhD students and staff members. ARPAC suggests that campus administrators consider moving some units out of Fleming or other spaces to allow MCEN more room and more contiguous space.

Staff

Growth in the student count will require further staff growth. ARPAC suggests that the unit continue with staff hiring. Of course, space must be identified for increased staff numbers; the department's strategic plan should account for this.

Recommendations

The members of ARPAC address the following recommendations to the Department of Mechanical Engineering (MCEN) to the offices of responsible administrators:

To the Unit:

Inclusive Excellence

1. Add action items to the strategic vision document that specifically address inclusive excellence. Create and submit an inclusive excellence narrative to the Office of Diversity, Equity and Community Engagement. Action items in the strategic plan should correspond to the inclusive excellence narrative.

2. Investigate whether office and laboratory space is assigned fairly based on research and teaching needs. If not, then move to rectify the problem.

3. Continue efforts to hire and retain diverse faculty members. Continue with mentoring efforts, with a particular focus on improved diversity and inclusion.

Climate – Faculty

4. Add action items to the strategic vision document that provide a route to improvements in the department's faculty climate.

5. Work with college and university administrators to communicate policies concerning uncivil and disrespectful behavior; these policies must include a written code of conduct as well as a faculty, staff, and student reporting structure. Reference existing campus structures and policies including the Professional Rights and Duties of Faculty Members document. In addition, MCEN needs to be prepared to report and act on violations, including applying sanctions, as called for by campus policies.

6. Report to the dean and to ARPAC on the creation and implementation of a written behavior code. Reach out to the Office of Institutional Equity and Compliance and to the director of faculty relations to institute faculty and staff training. All department members need to model appropriate behaviors, particularly faculty members in their interactions with staff and students.

7. Generate and maintain a list of faculty member service and teaching assignments. This list may include a subjective or objective assessment of the time commitment associated with a given service or teaching assignment.

8. Consider offering additional teaching credit for more difficult teaching assignments.

9. Consider refocusing service obligations toward full professors.

10. In cooperation with the college, establish and implement tenure and promotion and merit evaluation guidelines that conform to regent law and policy, and that incorporate standards for quality of research, and not just quantity. University rules require that academic units have clear written annual merit, reappointment, and tenure and promotion criteria.

Climate – Students

11. Train faculty in monitoring undergraduate team behavior. Consider bringing in outside organizations and gender issue experts to help teach undergraduates, especially those starting their CU studies, professional team conduct.

12. Use the upcoming undergraduate climate survey to address student climate issues. If necessary, make use of focus

groups to identify specific climate issues and possible methods for addressing them.

13. Continue work to attract women students, including addressing actionable tactics to recruit and retain women undergraduates in the MCEN strategic plan. One possible route to improved undergraduate student diversity is expanded outreach to high school and community college students.

14. Work with the Office of Data Analytics to track graduate and undergraduate student retention.

Growth

15. Work with college and university administrators to address space issues. Solutions may involve scheduling courses in unused hours and/or adding sections in order to relieve space constraints.

16. Continue efforts to hire additional staff. As part of this process, identify space for staff use.

17. Continue expanding the professional MS program.

18. Consider expanding the PhD program, consistent with demand for graduates in industry and academia.

19. Build on past success with interdisciplinary education by implementing the recommendations of the unit's Strategic Action Committee toward that end. Work with college and university administrators to reduce barriers to interdisciplinary teaching and research, possibly allowing credit for co-teaching, "consulting" with other departments

that wish to collaborate, and valuing interdisciplinary research in promotion and tenure decisions.

To the CEAS Dean:

20. Consider providing funds to attract diverse students. This may include increased stipends, PhD student signing bonuses, and paid childcare.

21. Recommend to MCEN that it use department resources to fund PhD student signing bonuses and student childcare support.

22. Support the unit in resolving faculty member incivility. If the unit finds that some faculty are unable to engage other faculty in a professional manner, then consider remedial actions, up to and including relocating such faculty members away from the department.

23. Work to find additional classroom space. Advocate for and continue to seek external funds to renovate existing labs and classrooms. Advocate for relief from the campus building and renovations moratorium.

24. Consider additional funding for MCEN PhD program expansion, consistent with demand for graduates in industry and academia.

25. Work with MCEN to improve and increase the number of graduate student packages. Consider an increase in TA/GPTI positions as part of this plan.

26. Work with MCEN and university administrators to appropriately reward interdisciplinary work, possibly allowing credit for co-teaching, “consulting” with other

departments that wish to collaborate, and valuing interdisciplinary research in promotion and tenure decisions.

To the Senior Vice Provost for Academic Resource Management:

27. Consider a waiver to the capital expenditure moratorium to allow an expansion and renovation of MCEN classroom space. The lack of space and outdated computing resources are serious current problems, even absent expected enrollment growth.

28. Find additional office and laboratory spaces for MCEN, and plan to improve the contiguity of department spaces.

To the Provost

29. Work with MCEN and the College of Engineering and Applied Science to appropriately reward interdisciplinary work, possibly allowing credit for co-teaching, “consulting” with other departments that wish to collaborate, and valuing interdisciplinary research in promotion and tenure decisions.

Required Follow-Up

The Department of Mechanical Engineering chair shall report annually on the first of April for a period of three years following the year of the receipt of this report (i.e., April 1st of 2020, 2021, and 2022) to the dean of the College of Engineering and Applied Science and to the provost on the implementation of these recommendations. Likewise, the dean shall report annually on the first of May to the provost on the implementation of recommendations addressed to the college. The provost, as part of the review reforms, has agreed to respond annually to all outstanding matters under their purview arising from this review year. All official responses will be posted online.