10-Year Program Review Report: University of Washington Department of Materials Science and Engineering

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Review Committee:

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1 Overview and Summary Recommendations

The Materials Science and Engineering Ten Year Review Committee is pleased to submit its report on the state of the MSE Department. The charge to the Review Committee focused specifically on the following degree programs:

- Bachelor of Science in Materials Science and Engineering (BSMSE);
- Master of Science in Materials Science and Engineering (MSMSE);
- Master of Science in Applied Materials Science and Engineering (AMP);
- Doctor of Philosophy (PhD)

With respect to these degree programs our summary recommendation can be stated succinctly:

We recommend the MSE degree programs identified above be given continuing status with the next review to be scheduled at the normal 10-year interval.

We based our review on the Self Study and supporting materials provided by the MSE Department and the Graduate School, along with a series of discussions held during the site visit with the various constituencies within the Department, including the chair and his leadership team,

junior and senior faculty, staff, center directors, faculty with joint appointments, undergraduate, and graduate students, and postdocs, and members of the external advisory board.

Our report has two main parts. First, there is a narrative discussion of general observations and recommendations highlighting some of the issues we believe deserve special attention if the Department is to flourish and achieve the potential which is commensurate with the stature and ambitions of the UW in general and the College of Engineering in particular. The second part of this report presents a more comprehensive list of detailed observations and recommendations intended to be useful at the departmental and college level.

2 General Observations and Recommendations

2.1 Recognition of Accomplishments Since 2004

The MSE Department has made remarkable progress under Professor Alex Jen's leadership. The transformations, though often challenging, have strengthened the programs of the Department substantially. Professor Jen has been creative and resourceful in guiding the Department through challenging budgetary times, with a successful record of entrepreneurship and collaboration to maximize the Department's impact despite limited resources. Appreciation for Professor Ohuchi's contributions to the undergraduate experience in his Associate Chair's role was expressed by numerous people we talked to, and he is to be commended for the support he provides to students and to his colleagues. Professor Luscombe's dedicated oversight of the graduate program has led to improved recruiting outcomes as measured by student quality metrics such as GPAs and GRE scores. Since the last Ten Year Review in 2004 undergraduate enrollment has grown from about 40 students per year to roughly 125 students (juniors and seniors). Graduate enrollment for the PhD degree has remained steady at roughly 60 students. However, grant funding has tripled to \$7.5M per year. Both the undergraduate and graduate programs (plus a strong corps of postdocs) are strong, and students are enthusiastic and of high quality.

This was also a period of transformation that required deft management to move a department that had a strong tradition in metallurgy and ceramics to a rather different focus emphasizing soft materials with new and dynamic programs in nanomaterials, biomaterials, photonics, energy generation and storage. This shift has allowed the Department, with limited faculty resources, to remain at the cutting edge of contemporary MSE topics while also adapting its curricular offerings at both the undergraduate and graduate levels to exploit the growing emphasis in engineering in the molecular and nanoscience domains. Although this shift has perforce meant a reduced emphasis on the former pillars of the Department, it is consistent with the broader trends in engineering and reflects a deliberate strategy to grow in emerging areas of MSE where this Department can achieve world class status. It can be argued that it is gratifyingly successful in that effort. The Department has forged strong partnerships with other units on campus in recent years to the palpable benefit of both the MSE Department as well as the partner units. The result is a much stronger intellectual force than the simple sum of the individual units. Indeed, materials science at the UW is ranked among the leading programs in the world in terms of citations to publications in the field. This is in no small part a measure of the deliberate actions initiated by Professor Jen and his colleagues to forge strong partnerships with other units on campus.

2.2 Recommendation for Growth

The challenge for the Department is to maintain this momentum and build on it. The Ten Year Review of 2004 suggested that the Department was undersized in comparison with its peers and

recommended that its ambition to be in the top 20 programs in the nation could be greatly aided by the addition of several faculty positions. Unfortunately, the Department is essentially the same size as it was in 2004 (joint appointments would require further elaboration). In the opinion of this 2016 Review Committee the 2004 perspective is even more compelling today. It can be argued that Materials Science and Engineering will in all likelihood play an ever increasing role in the coming decades as any number of major societal grand challenges will demand ever more sophisticated technological solutions in areas such as renewable energy, manufacturing materials, global health and health care more generally, and biomaterials. The centrality of materials in fostering an interdisciplinary culture and in linking diverse science and engineering disciplines has been a hallmark of great industrial laboratories like Bell Labs in the past and in the emergence of leading programs at several universities (e.g., the University of California at Santa Barbara, the University of Illinois, and Cornell University). It is, of course, de rigueur for Review Committees to urge the growth of the unit under review. But that fact should not be allowed to trivialize the compelling case that exists for a serious examination of the rationale for substantial growth of the MSE program at the UW.

We have already mentioned the growing centrality of molecular and nanoscale engineering to other engineering disciplines. Historically, MSE has been a younger sibling in the family of engineering disciplines. But as the family has matured, it is not inappropriate for MSE to play a more adult role both in terms of size and responsibility and to benefit from a greater recognition of its critical role in enhancing the work of other departments.

Second, MSE is a critical partner for departments in other units of the UW whether in the Health Sciences, or the physical sciences in the College of Arts and Sciences, or the College of the Environment or the College of the Built Environment. For example, as Professor Xu stated in our meetings, the top programs in condensed matter physics are always associated with the best MSE programs. His appointment in both Physics and MSE is an excellent example of opportunities to strengthen both units.

Likewise, the active role that Professors Jen and Luscombe have played in the NSF Science and Technology Center led by Professor Dalton in Chemistry was critical to the notable success of that program. Today, involvement of a number of MSE faculty in the Clean Energy Institute (CEI) represents both a great opportunity for MSE as well as powerful asset for the CEI. There are other examples including Professor Zhang's collaboration with faculty in the School of Medicine that could be cited but these illustrate the growing and essential role of MSE in the broader UW research ecosystem.

Given the plan for overall growth in the College of Engineering, there are opportunities for each unit to develop growth targets.

To this end, we strongly recommend that the Department, in consultation with the College, engage in a critical planning exercise that not only refines its vision for the future of the Department but also spells out in some detail the potential opportunities and rewards for the program if it were to grow to between 15 and 20 faculty members over the next five to ten years.

Such growth would also go a long way toward rebalancing the faculty age profile which is very top heavy and in a year or two will have no assistant professors at all.

2.3 Partnership Opportunities and Infrastructure Improvements

There are additional considerations that apply to the above recommendation. The presence of the CEI affords excellent opportunities for MSE. Moreover, the CEI will not be truly successful without strong involvement by MSE. Therefore, strengthening the partnership between the two

is imperative including not only shared faculty appointments but also space allocations. Joint appointments with other key departments should also be actively explored and exploited.

An even more compelling opportunity is currently being explored by the UW with PNNL. Every effort should be made by the College and the UW more generally to make it happen. The proposed Northwest Institute for Advanced Materials (NIAM) — the proposed joint venture between the UW and PNNL — provides an enormous opportunity for both parties, and a physical facility on campus or in close proximity to house PNNL scientists who would enjoy joint appointments in appropriate UW departments would have powerful advantages to both partners. This is especially important for MSE not only because of the substantial overlap of research interests between PNNL and MSE, but also because of the additional instrumentation resources and expertise at PNNL — especially at EMSL (Environmental and Materials Science Laboratory), the PNNL user facility.

In this context, it occurs to the Review Committee that a carefully designed strategy involving some of the above elements could also serve as a powerful argument with the State Legislature for investment in capital facilities for which planning funds have already been allocated. A concerted appeal to Olympia with the combined support of the College of Engineering together with the College of Arts and Sciences for funding for the proposed facility with its potential synergy with the NIAM mentioned above might be intriguing enough to overcome the significant barriers to State funding of facilities that has been experienced in recent years.

This strategy should include a serious discussion of the current space allocation for MSE. Not only are the labs, offices and faculty in four different locations on campus, but the physical distance approaches a kilometer for the most distant locales. This fragmentation is not conducive to building a strong intellectual community and disadvantages the students as well as the faculty. Given the prospects for expanded facilities both with NanoES and the CEI initiative this seems like a propitious time to consider some consolidation both for reasons of intellectual overlap but also in recognition of the source of the Sound Transit settlement that is partially funding NanoES.

Finally, one other infrastructure issue should be highlighted in this context. Increasingly, the need for high resolution electron microscopy is becoming urgent for a wide range of research programs on campus. Specifically noted were shortcomings with "high resolution transmission electron microscopes, scanning tunneling electron microscopes, and angle resolved photoemission spectroscopy. In addition, we are also weak at novel material synthesis using techniques such as vapor transport and molecular beam epitaxy." The current situation for electron microscopy is suboptimal to say the least. This has been a perennial problem on campus and has reached the point now where it is seriously impacting the effectiveness of a number of groups. The problem is that this issue has historically been left to individual faculty members or at best a department. But the scale of the problem is beyond the scope of an individual department. This should be addressed coherently at the institutional level, both in terms of the instrumentation as well as ongoing staff and maintenance support to ensure availability of a reliable, state-of-the-art facility. The opportunity to explore such an upgrade of an essential part of the UW's core research infrastructure seems both timely and constructive.

2.4 Summary

This overview is intended to provide some context for our recommendations. Although we could elaborate on many of the other recommendations that follow, with arguments that we consider substantive, we do not wish to detract from the core complex of issues that we have outlined above. We feel strongly that this is a unique time to act intentionally to help move the MSE Department to the next level of vitality and impact. We believe some of the factors that we have touched on

above provide a sensible framework for undergirding a deliberate strategy that can redound to the benefit of the Department, the College, the UW and the region.

3 Detailed Observations and Recommendations

The following sections provide more comprehensive listings of our observations and recommendations, which we intend not to be prescriptive, but rather to be helpful to the Department, the College of Engineering, and the UW in further strengthening the program. Please note we have numbered these items to aid in referencing rather than to imply or impose any prioritization.

3.1 Program Highlights and Opportunities

1. MSE has demonstrated a strong record of program improvement since the previous 10-year review. The transition from separate ceramic and metallurgy programs to a unified MSE program has been very successful.

2. The Department's undergraduates were seen to be engaged and enthusiastic with regards to their experiences across the board, including both curricular and extra-curricular activities.

3. There is clear evidence of an effective leadership team in Professors Jen, Ohuchi, and Luscombe.

4. The Department has been particularly successful in the leveraging of joint appointments and center opportunities (e.g., the Center for Materials and Devices for Information Technology Research – CMDITR (NSF-STC); Genetically Engineered Materials Science and Engineering Center – GEMSEC (NSF-MRSEC), the Clean Energy Institute, the Molecular Engineering and Sciences Institute, etc.)

5. The Department has good engagement with local industry, with benefits both to educational and research programs.

6. Faculty holding joint appointments report satisfaction with their experience.

7. Undergraduate teaching facilities are effectively used and well run, and students benefit from hands-on lab and project activities.

8. Diversity considerations are evident in regards to student recruiting. Graduate and undergraduate student demographics are comparable to national norms with respect to gender, and Washington State norms with respect to underrepresented minorities. The 10-year average of 30% PhDs being awarded to women is noticeably above the ASEE-reported MSE national average of 24%.

9. There were multiple expressions by faculty and students of appreciation for staff contributions. The MSE staff is doing well in its work of supporting the Department's instructional and research missions.

10. The undergraduate and graduate curricula are sound. The undergraduate program was recently accredited by ABET.

11. There is a clear 10-year history of strong research productivity with high impact, particularly in regards to citations and center leadership and participation.

3.2 Program Challenges

1. There are relatively few faculty members who have come up through the ranks, but the new hires are excellent. It will be important to retain and mentor faculty as they progress through there their careers.

2. Related to the rank of recent hires, faculty career-stage demographics might be skewed for a period of time.

3. Related to the previous item, developing leaders among the junior faculty may need to be fast-tracked more than might otherwise be the case.

4. MSE's distributed facilities impede community building, especially among grad students (and faculty).

5. There is evidence of uneven institutional investment in research infrastructure (equipment and facilities) supporting MSE's activities. Research-capable microscopy was identified as being particularly problematic by both faculty and students.

6. Graduate students expressed a sense of being locked-in to particular advisors from the very beginning due to PI-based recruitment, which they did not see as always being optimal either for students or PIs.

7. The representation of women on the faculty is low, and grad students expressed an interest in seeing more women being interviewed (at a minimum) and being hired.

3.3 Recommendations

3.3.1 Internal (i.e., departmental):

1. Expand executive committee participation to encourage leadership participation of junior faculty. Even in a small department working everything out in faculty meetings might not be optimal.

2. Communicate on actions taken in response to student input. Students noted they weren't always sure they were being listened to, even in instances in which action was taken, so communication is key.

3. Construct a 5/10-year strategic plan with growth targets/mechanisms. This does not reduce the need and benefit of being nimble, opportunistic, and entrepreneurial, but it can help in longer range initiatives and partnerships with other campus units.

4. Focus on expanded and intentional community building among grad students and faculty, especially in face of the distributed nature of labs and offices. It was suggested that holding a social hour with food before the Departmental seminar could help build community, as would giving more emphasis to recurring social events throughout the year to build community.

5. Related to the above, create common areas for grads and undergrads to work and socialize. Computer labs are not necessarily optimal for this. Maybe the current computer lab could be repurposed, in part, for such a gathering place.

6. Department needs to think about branding and promotion. Might want to consider inviting chairs of top ten MSE departments to give seminars (over a several year period) both to educate them about the quality of the Department as well as for UW MSE to be better informed about best practices at other MSE Departments.

7. MSE might want to consider mounting its own Career Fair rather than only participating in the College of Engineering Career Fair.

8. Undergraduates felt that career guidance and help with internships was good, but wished there was more support and guidance for them in applying for fellowships or graduate school.

9. Mentoring of new faculty is critical, but this can be difficult in smaller departments. It perhaps would make sense to engage emeritus faculty, and/or reach outside the Department. This must be approached more systematically.

10. Ensure sustained departmental equipment maintenance and upgrades. It was noted that very little equipment has been purchased in the last ten years with funds other than the Student Technology Fee funds.

11. Integrate local facilities with centralized facilities to reduce redundancy and improve efficiency. This will involve MSE and other campus units especially with the state funded CEI (see below)

12. Ensure grad student keycard access to needed facilities (e.g., the Hall Building).

13. Consider departmentally-based rather than PI-based recruitment (initial departmental support with lab rotation). This could help optimize PI/RA fit.

14. Broaden advisory board membership beyond alumni to include more key figures from important industries.

15. When hiring be intentional in trying to build faculty applicant pools that include women and other under-represented groups. Err on the side of doing extra interviews rather than short-listing diversity away.

16. Consider growing the Applied Master's Program via a coursework-only MS. The limited size of the faculty and absence of funds to support AMP student research is a serious problem for the thesis-AMP.

17. Expand linkages with other departments (e.g., Bioengineering, ME, etc.)

18. The External Advisory Committee supported the idea of more internships for students. They also emphasized the importance of considering the area of computer simulation and modeling for future faculty hires.

19. Apparently MSE 310 is a course taught largely by Boeing staff. The Department might want to consider a parallel course in which scientists and engineers from other local companies give lectures (pro bono) both to build connections with local industry and also give the students a more balanced perspective on industrial activities and opportunities.

3.3.2 External (i.e., College, University)

1. The UW could benefit significantly if it were to recognize and act on the centrality of materials across all engineering and science.

2. Develop a plan for MSE growth in consort with planned COE growth.

3. The Clean Energy Initiative Institute provides a major opportunity for expansion, collaboration, and new facilities. MSE should continue to play an important role in this effort.

4. Leverage unique opportunity to support and facilitate the Northwest Institute for Advanced Materials (NIAM) between the Pacific Northwest National Laboratory (PNNL) and UW. Historical institutional barriers to collaboration have been lowered significantly in recent years.

5. Continue strengthening ties between departments.

6. Campus-wide high-resolution microscopy facilities should be significantly expanded and improved.

7. Help manage leadership development for mid-career faculty. This issue reaches beyond a single department, and there could be economies of scale via college-level activities. This also can further develop cross-departmental ties among future leaders.