Response to Computer Engineering portion of EAC's Draft Statement

February 13, 2007

This document is the response of UCR's Computer Engineering Program to EAC's Draft Statement regarding the 2006 review of the Computer Engineering program at the University of California Riverside. That statement noted "weaknesses" with respect to Criterion 2 and Criterion 3, respectively.

1 Criterion 2: Program Educational Objectives

The description of the weakness with respect to Criterion 2 reads as follows:

> Criterion 2. Program Educational Objectives: Criterion 2 states, "... program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve." The program's objectives are not broad statements that describe the accomplishments of computer engineering graduates and their achievements; instead they describe skills more appropriately articulated in program outcomes. In addition, it is not clear that these objectives were reached based on the needs of the program constitutuents (students, faculty, employers, alumni, advisory boards, and the community at large.) Since these objectives were not defined based on the needs of program constituents, it is not clear how the results are used to improve the program outcomes and for graduates to attain the objectives.

Specifically, the Draft Statement's finding for Criterion 2 identifies three areas where clarification and/or remediation is required:

1. the appropriateness of the current PEOs relative to EAC's definition of "program educational objectives."
2. the process by which the PEOs are established
3. how the results (of PEO assessment) are used to improve outcomes and attainment of PEOs.

We take each of these in turn.

1.1 Appropriateness of current PEOs

We consider the draft finding to be accurate and relevant in this regard. The current PEOs are the result of some confusion about the distinction between the notions of "outcome" and "objective" on the part of our constitutents, including the faculty. (It should be noted that this is our program's first time being accredited under the 2000 criteria, and our PEOs have not evolved as quickly as they could have.)

Based on preliminary consultations with our constituents, and in response to this aspect of the Draft Statement, the chairs of CS&E and of EE have proposed a new set of objectives, which (1) are *"broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve"* and (2) are directly measurable. The proposed wording is as follows:

> *Graduates of UCR's BS degree program in Computer Engineering will be capable of achieving:*
>
> - *success in post-graduation studies as evidenced by:*
> - *satisfaction with the decision to further their education*
> - *advanced degrees earned*
> - *professional visibility (e.g., publications, presentations, patents, inventions, awards)*
> - *international activities (e.g., participation in international conferences, collaborative research, employment abroad)*

- *success in their chosen profession as evidenced by:*
  - *career satisfaction*
  - *promotions/raises*
  - *professional visibility (e.g., publications, presentations, patents, inventions, awards)*
  - *entrepreneurial activities*
  - *international activities (e.g., participation in international conferences, collaborative research, employment abroad)*

1.2 The process by which the PEOs are established

In response to this finding, we have reduced the program's list of constituents to include: faculty, students, alumni, and advisory boards[1] and expanded the process by which PEOs are established as described below. As noted in the Self-Study, however, in past PEOs have been developed in consultation with our advisory boards[2] and other constituencies, notably via alumni surveys and exit surveys of graduating seniors.

The revised process, which we are following for the necessary revision of the PEOs, is as follows:

> A Request for Comment (RFC) has been sent to the following subsets of the various constituents:[3]
>
> - members of the student chapter of IEEE
> - members of the student chapter of ACM
> - members of the Undergraduate Leadership Council
> - members of EE's board of advisors
> - members of CS&E's board of advisors
> - all alummni of the program

[1]The advisory boards include a sampling of employers and potential employers. We cannot conceive of a meaningful way of consulting "the community at large" for input that is relevant specifically to the Computer Engineering program.

[2]See, for example, the report of August 2005 from CS&E's advisory board included in the self-study.

[3]The list of constitutents has been revised as discussed in the next subsection.

- all CS&E faculty
- all EE faculty

This feedback will be discussed at this spring's meetings of the advisory boards for EE and for CS&E, respectively.

All feedback, including the minutes of those meetings, will then be considered by the accreditation committees for CS&E and for EE. These committees will draft a final version of the PEOs, which will be voted on by the faculty of each department. That final version will be published on the programs web site in May 2007 and in the next edition of UCR's General Catalog.

Input on the suitability of the PEOs will be solicited at the annual meetings of the advisory boards and on the annual surveys of the other constituents. If a change is indicated a concrete proposal will come from the faculty and Requests for Comment (RFCs) will be sent to the other constituents. The faculty will review the feedback and vote on whatever revisions are indicated.

1.3 How results of PEO assessment are used

The mechanisms for determining achievement for PEOs include the following:

- Meetings and surveys of departmental Advisory Boards for CS&E and EE – These boards consist of senior engineering managers and researchers from both industry and academia. The objective is to obtain feedback concerning our graduates from people in the best position to comment on their performance is and what it should be.
- Exit surveys of graduating seniors – The objective of this survey is to obtain feedback on our program from one of its key constituents while the program is still fresh in their minds.
- Alumni survey – The objective of this survey is to obtain feedback from one of our key constituents after they have begun to implement the fruits of our program in their lives and careers.

This material is reviewed by the faculties at their respective annual retreats and concrete actions are taken to remedy perceived problems. Examples of such actions include:

- As a result of input from advisory boards, a course on technical communications (Engineering 180) has been established and adopted as a requirement for Computer Engineering, thereby enhancing the degree to which graduates will have achieved outcome (g) and the degree to which outcome (g) will be assessed.

- As a result of concerns raised on the exit surveys of seniors, the College of Engineering established a position of Career Development and Placement Officer to assist graduating students and alumni in pursuit of their careers and the degree to which they achieve the PEOs.

- Also as a result of those exit surveys, we have have established a "course-materials fee" to pay for laboratory supplies and the maintenance and replacement of rapidly depreciating equipment such as desktop computers, thereby enhancing their ability to achieve outcome (k).

- Finally, as result (in part) of dissatisfactions registered in exit surveys by graduating Computer Engineering majors, UCR appointed a Task Force on Student Success, chaired by Reza Abbaschian, Dean of the Bourns College of Engineering, who made use of the Colleges feedback and assessment tools in leading this group. The Task Force recommended numerous changes to the freshman experience, student advising, student surveys, and University investments in support of teaching and learning. At least two of the recommended changes were pioneered in Engineering: the development of "learning communities" in which students take several introductory-level courses together, and the establishment of some tutoring and mentoring services in campus dormitories.

2 Criterion 3: Program Outcomes and Assessment

The description of the weakness with respect to Criterion 3 reads as follows:

> Criterion 3. Program Outcomes and Assessment Criterion 3 states, "There must be a process to produce these outcomes and

an assessment process, with documented results, that demonstrates that these program outcomes are being measured and indicates the degree to which the outcomes are achieved. There must be evidence that the results of this assessment process are applied to the further development of the program." Course objectives are defined for each course but they are not clearly related to program outcomes that are referred to as departmental outcomes. It is stated in the report that the college will administer a new assessment tool in the fall of 2006 but the process used presently in measurement of program outcomes is not documented. Achievement of program outcomes is demonstrated using course objectives and grades in homework assignments and exams. Sufficient evidence was not provided to demonstrate students attain the outcomes articulated by the computer engineering program.

The following two paragraphs from CAC's Draft Statement for its concurrent site visit for UCR's Computer Science program, which has the same eleven A-K outcomes and the same assessment process as the Computer Engineering program, eloquently explains the situation:

> *The program shares assessment services with the other programs in the Bourns College of Engineering, which employs a number of assessmennt vehicles, both indirect and direct, to provide insight into its performance. A detailed data gathering plan employs direct assessment data from course examinations every term. In addition, data from end of term course evaluations and faculty assessments are gathered every term. There also are annual alumni surveys, annual employer surveys, and the program gathers data from its very active Board of Advisors annually. It has a documented set of four educational objectives and eleven related outcomes for graduating students that are measureable (Standards I-1 and I-2). Data relative to the objectives and outcomes are collected on a detailed schedule and the results are captured in a very powerful and easily accessible database (Standard I-3). The assessment process addresses each outcome and educational objective at least once a year and usually once a term (Standard I-4). On-line copies of minutes retained by the program show that the faculty members meet regularly to analyze and evaluate the data (Standard I-6). The Self-Study and provided documentation*

made available during the visit document a number of multi-cycle, data-driven, examples of curricular and program improvements (Standard I-5).

The visiting team notes that the self-study provided prior to the visit contained numerous inconsistencies and lacked some required material. In particular, requested assessment documentation and analysis results were not provided. While this material was provided during the visit, the team had to divert considerable effort to evaluating the objectives and assessment criteria, effort that should have been invested in other activities.

In any case, EAC's Draft Statement for Criterion 3 identifies three issues that need clarification and/or remediation:

1. course objectives are not clearly related to program outcomes
2. the process for measuring program outcomes is not documented
3. assessment of program outcomes is measured using course objectives and grades in homework assignments and exams, which does not demonstrate attainment of the outcomes.

We discuss these issues in the following three subsections.

2.1 Relating course objectives to program outcomes

We disagree with this aspect of the finding. Section B.3.2 of the Self-Study provides a detailed description of how course objectives (not to be mistaken with program objectives) are established for each course in the curriculum, and how those course objectives pertain to the A-K outcomes — Table 8 of the Self-Study showed an example. The Self-Study also explains the "Relevance Matrix" showing the weight a given course places on different outcomes. And finally, it shows the formula we use to calculate the degree to which our curriculum achieves the outcomes and the degree to which students are learning what we intend for them to learn.

Note each course's *course file*, on display during the site visit, contained a copy of that course's *course objectives* plus a copy of that course's *relevance matrix*.

2.2 Documentation of the process for measuring program outcomes

Section B.3.2 of the Self-Study contains an explaination of the process. In addition, there was a copy of the full documentation among the materials made available at the site visit. Section 3 of this response contains an explanation of principles on which our direct-measurement methodology is based.

In addition, we are experimenting with new ways to assess outcomes. As the Self-Study pointed out, and the reviewer mentioned in the Draft Finding for Criterion 3, we implemented a new survey with the entering freshman class in Fall 2006. This survey was designed to measure expectations at the beginning of the freshman year, and a second survey the following Fall is designed to measure the extent to which the actual experience matched the expectations. We will complete the first cycle of this assessment process in Fall 2007.

2.3 Use of grades as an assessment tool

Because a single course objective maps to multiple outcomes, and because some homework problems and test questions also pertain to multiple outcomes, it has been argued that our measurement process does not isolate student achievement outcome-by-outcome. We recognize that ABET frowns on use of overall course grades as an assessment tool because of the coarseness of the measure. As we documented in our process of mapping of course objectives to program outcomes via weighted relevance matrices, an accurate picture of sufficient resolution emerges — see Section 3 for details.

That said, however, we will make an effort going forward to design homework problems and test questions to test individual outcomes.

3 Measuring Achievement of Program Outcomes

Per ABET's Criterion 3, "Program Outcomes and Assessment": *"There must be ... an assessment process, with documented results, that demonstrates that these program outcomes are being measured and indicates the degree to which the outcomes are achieved."*

The normal way to measure the degree to which students achieve a given educational objective is to:

- assign *items*[4] to the students,
- *grade*[5] each student's performance on each item,
- *weight* each item by the degree to which it measures that objective,[6]
- aggregate each student's grades by applying some algorithm to those grades and weights.

Obviously, a given item can measure the achievement of more than one objective, but in such cases, the item may need a different weight wrt each objective — usually this weight matrix is sparse. The degree to which each student achieves each objective is given by the product of the grade matrix times the transpose of the weight matrix.[7]

Our implementation is based on ideas from the paper, *Designing and Teaching Courses to Satisfy the ABET Engineering Criteria*, Journal of Engineering Education, January 2003 by Richard M. Felder and Rebecca Brent.

Each of our courses has been given an associated list of six or so *course objectives*. A given offering of a course, involves many graded *items*, which we organized into *instruments* (i.e., exams and assignments). For each instrument, students' grades and items' weights are recorded in *gradebooks*. Thus, for each instrument, a course offering's gradebook holds two matrices:

- The instrument's *grade matrix*[8] holds each student's grade on each item.

[4] i.e. problems and questions

[5] i.e. score

[6] This weight is that item's degree of *coverage*, *scrutiny*, *relevance*, or *efficiency* wrt that objective.

[7] Equivalent results cannot be obtained by aggregating first using a single weight per task and then multiplying those aggregate numbers by a weight per objective, i.e., to use a weight matrix that is the outer product of a vector of per-task weights with a vector of per-objective weights. In such a case the achievement per student of the various objectives would be fullly correlated, i.e., scalar multiples of each other. Gloria Rogers makes a related point in her paper *Do Grades Make the Grade for Program Assessment*, available online from ABET: *"... nor do [course grades] provide information about what topics or concepts he or she did not understand ..."*

[8] a.k.a. score matrix

- The instrument's *weight matrix*[9] holds the degree to which, in the judgment of the instructor, each item measures the achievement of each course objective.

Processing. We aggregate measurements by weighted averaging,[10] and we aggregate weights by summing. Specifically, a student's aggregate grade relative to a given objective is the weighted average[11] of his/her per-item grades.[12]

We obtain an instrument's *achievement matrix* by aggregating over the items on that instrument, i.e., by multiplying the instrument's grade matrix by the column-normalized transpose of its weight matrix. The result shows each student's aggregate grade with respect to each objective.

An instrument's *achievement vector* is obtained by averaging per-objective achievements over all students, with equal weight per student. An instrument's *weight vector* is obtained by summing the weights over all items.

Linking course objectives to program outcomes. With each course we associate a *course matrix* telling the degree of relevance of each of the course's objectives to each of the A-K outcomes. It is sometimes appropriate and helpful to have some of the A-K outcomes as course objectives. In such cases, those objectives are given the maximum weight.

We assume a linear model for weight in the sense that the weight each item from a given instrument gives each of the A-K outcomes can be obtained by multiplying the instrument's weight matrix with the offering's course matrix. This implies that the outcome-oriented achievement and weight vectors are obtained by multiplying the corresponding objective-oriented vectors by the course matrix.

To aggregate achievement vectors over a given set of course offerings, take

[9] a.k.a. relevance matrix

[10] More sophisticated methods exist. The psychometrics literature contains a century of statistical research on testing. The most applicable work is latent-trait theory (a.k.a. "item-response theory"), where the latent traits of interest are the A-K outcomes.

[11] The weighted average of a list of numbers $S_1, S_2, \cdots, S_n$ having respective weights $W_1, W_2, \cdots, W_n$ is $(W_1S_1 + W_2S_2 + \cdots + W_nS_n)/(W_1 + W_2 + \cdots + W_n)$, and the weight of that average is $W_1 + W_2 + \cdots + W_n$. It is easy to show that the weighted average of weighted averages is the weighted average of the combined lists.

[12] The grades should be normalized grades, e.g., normalized by dividing each by the highest grade attained by anyone on the corresponding item.

their outcome-by-outcome weighted averages, where each offering's weight for a given outcome is its weight of that outcome times its enrollment. Ultimately, we measure the degee to which a curriculum is achieving its program outcomes by aggregating the achievement vectors of its required upper-division courses.