CRITERION 3. STUDENT OUTCOMES

A. *Student Outcomes*

List the student outcomes for the program and indicate where the student outcomes are documented. If the student outcomes are stated differently than those listed in Criterion 3, provide a mapping to the (a) through (k) Student Outcomes.

The Electrical Engineering program Outcomes are:

[http://www.coe.montana.edu/ee/info/ee_abet.htm]

Designation	**Program**	**Outcome**
a	EE&CpE	An ability to apply knowledge of mathematics, science, and engineering.
b	EE&CpE	An ability to design and conduct experiments, as well as to analyze and interpret data.
c	EE&CpE	An ability to design a system, component, or process to meet desired needs.
d	EE&CpE	An ability to function on multi-disciplinary teams.
e	EE&CpE	An ability to identify, formulate, and solve engineering problems.
f	EE&CpE	An understanding of professional and ethical responsibility.
g	EE&CpE	An ability to communicate effectively.
h	EE&CpE	The broad education necessary to understand the impact of engineering solutions in a global and societal context.
i	EE&CpE	A recognition of the need for, and an ability to engage in lifelong learning.
j	EE&CpE	A knowledge of contemporary issues.
k	EE&CpE	An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.
l	EE&CpE	Knowledge of the principles of project management and design trade-offs.
m	(n/a)	(*Program outcome "m" was deleted in 2004, as explained at the 2009 ABET review*)
n	CpE	An ability to program microcontroller/microcomputer systems using assembly and high-level languages.
o	CpE	An ability to design digital systems using modern design tools.
p	CpE	An ability to analyze electrical and electronic systems.
q	CpE	An ability to implement real-time systems.
r	EE	An ability to analyze and synthesize electronic devices and electrical systems.

The EE program Outcomes are published on the departmental web site http://ece.montana.edu/info/ee_abet.htm, and also in the Montana State University course catalog: http://catalog.montana.edu/undergraduate/engineering/electrical-computer-engineering/electrical-engineering/ .

NOTE that Outcomes n, o, p, and q are for the *Computer Engineering* program, and are simply listed here for cross-reference purposes: these outcomes will not be discussed or covered further in this document.

Program outcomes a-k are mandated by ABET Criterion 3. Outcomes l and r are EE program-specific outcomes determined by our Outcomes Assessment process summarized in Section 4 below.

B. Relationship of Student Outcomes to Program Educational Objectives

Describe how the student outcomes prepare graduates to attain the program educational objectives.

Table 3-1 shows how each of our program Outcomes relate to our educational Objectives.

Table 3-1. Relationship of Outcomes to Objectives

	Educational Objectives		
Program Outcomes	**1. 1. Pursue a professional career based on an education in the fundamentals of Electrical and Computer Engineering**	**2. Engage in post-graduate education programs**	**3. Provide a positive impact to the engineering community and to the community at large**
a: An ability to apply knowledge of mathematics, science, and engineering.	X	X	
b: An ability to design and conduct experiments, as well as to analyze and interpret data.	X	X	
c: An ability to design a system, component, or process to meet desired needs.	X	X	X
d: An ability to function on multi-disciplinary teams.		X	X
e: An ability to identify, formulate, and solve engineering problems.	X	X	X
f: An understanding of professional and ethical responsibility.	X		X
g: An ability to communicate effectively.	X	X	X
h: The broad education necessary to understand the impact of engineering solutions in a global and societal context.		X	X
i: A recognition of the need for, and an ability to engage in lifelong learning.		X	X
j: A knowledge of contemporary issues.		X	X
k: An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.	X	X	X
l: Knowledge of the principles of project management and design trade-offs.	X		X
r. An ability to analyze and synthesize electronic devices and electrical systems.	X	X	

As noted in Criterion 2, the Program Objectives describe the kinds of engineers we wish to produce. These engineers need a core set of abilities, and these attributes are reflected in the Program Outcomes listed above. Some Outcomes, i.e., c, e, g, and k, broadly support the Objectives while others have been chosen to provide specific abilities necessary for technical competence specifically within the EE field, in the workplace, or in advanced education and research.

CRITERION 4. CONTINUOUS IMPROVEMENT

This section of your Self-Study Report should document your processes for regularly assessing and evaluating the extent to which the student outcomes are being attained. This section should also document the extent to which the student outcomes are being attained. It should also describe how the results of these processes are utilized to affect continuous improvement of the program.

A. Student Outcomes

It is recommended that this section include (a table may be used to present this information):

1. A listing and description of the assessment processes used to gather the data upon which the evaluation of each student outcome is based. Examples of data collection processes may include, but are not limited to, specific exam questions, student portfolios, internally developed assessment exams, senior project presentations, nationally-normed exams, oral exams, focus groups, industrial advisory committee meetings, or other processes that are relevant and appropriate to the program.

Our outcomes assessment process consists of the following five steps:

i. In order to obtain direct evidence of outcomes achievement, we use a specific set of *Outcomes Indicator Courses*. The choice of which courses are Outcomes Indicator Courses is based on faculty consensus regarding our learning outcomes and foundational principles in required courses in the Electrical Engineering curriculum. Many of the Outcomes Indicator Courses are from the sophomore and junior years of the curriculum because that is the place where many of the key required courses are present, providing the core of the EE curriculum. Several of the more abstract Outcomes are assessed in the senior design sequence classes (EGEN 310, EELE 488, EELE 489) and in the engineering ethics class (EELE 487).

   The instructor of each Outcomes Indicator Course selects a set of *specific graded components of that course (exam problems, homework problems, projects, or other graded coursework) that address the associated Outcomes*. Achievement of Outcomes is assessed by percent scores for these designated examinations, written and oral communications, laboratory assignments, homework assignments and other student work that are strongly correlated with each of the program's Outcomes. In some cases, it has been convenient to collect Outcomes information for courses other than the Outcomes Indicator Courses, but because the Indicator Courses are part of the required curriculum that all students must take, we give more emphasis on assessment and evaluation based on the Indicator Course data.

   The Outcomes Indicator Courses are:

Outcome	**Courses Evaluating**
a	An ability to apply knowledge of mathematics, science, and engineering.
	201, 308, 317, 334, 355, 488, 489
b	An ability to design and conduct experiments, as well as to analyze and interpret data.
	201, 317, 334, 355
c	An ability to design a system, component, or process to meet desired needs.
	371, 465, 488, 489, EGEN 310
d	An ability to function on multi-disciplinary teams.
	488, 489, EGEN310
e	An ability to identify, formulate, and solve engineering problems.
	308, 334, 355, 488, 489, EGEN 310
f	An understanding of professional and ethical responsibility.
	487, 488, 489, EGEN310
g	An ability to communicate effectively.
	317, 355, 465, 488, 489, EGEN 310
h	The broad education necessary to understand the impact of engineering solutions in a global and societal context.
	487, 488, 489, EGEN 310,
i	A recognition of the need for, and an ability to engage in lifelong learning.
	334, 487, 488, 489
j	A knowledge of contemporary issues.
	487, 488, 489
k	An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.
	308, 317, 355, 465, 488, 489, EGEN 310
l	Knowledge of the principles of project management and design trade-offs.
	488, 489, EGEN 310
r	An ability to analyze and synthesize electronic devices and electrical systems.
	308, 317, 488, 489

The mapping of courses onto the EE Program Outcomes is indicated below:

		Recent Prof.	***a***	***b***	***c***	***d***	***e***	***f***	***g***	***h***	***i***	***j***	***k***	***l***	***r***
201 (F/S)	*2*	Becker	■	■											
308 (F)	*4*	J.Shaw	■				■						■		■
317 (F)	*5*	Becker	■	■					■				■		■
334 (F)	*4*	Nakagawa	■	■			■				■				
355 (S)	*5*	Nehrir	■	■			■		■				■		
371 (F)	*1*	Larimer			■										
465 (S)	*3*	Larimer			■				■				■		
487 (S)	*4*	Maher						■		■	■	■			
488 (F/S)	*12*	Nakagawa/Gao	■		■	■	■	■	■	■	■	■	■	■	■
489 (F/S)	*12*	Nakagawa/Gao	■		■	■	■	■	■	■	■	■	■	■	■
EGEN310	*8*	Staff			■	■	■	■	■	■			■	■	

At the conclusion of the semester, the Outcomes Indicator Course instructor pulls out the performance scores on the graded assignments attributed to the assigned Outcome(s), and reports to the Department Head the number of EE students and the scores for those elements. The Department Head collects the Outcomes Indicator scores for each of the classes and does a numerical average to get the composite attainment score for the individual Outcomes (see Figures 4-2 and 4-3 below).

ii. The results of this assessment are presented to both the ECE faculty at the annual faculty retreat and to the ECE External Advisory Council at the annual fall meeting for analysis. The faculty discuss and review the scores for each Outcome, paying particular attention to trends in scores that become evident over several years of assessment processes. Approximately every third year (triennial), the evaluation includes a careful examination of trends and changes.

iii. An Outcome may be modified, with input from the ECE External Advisory Council and faculty, if it seems appropriate. This potential modification occurs approximately triennially. See section 3 above.

iv. Courses instrumental in measuring Outcomes (targeted Outcomes Indicator Courses) that exhibit low scores or a downward trend are examined for ways to better achieve the corresponding Outcomes. The faculty are also interested in determining the specific course content used to help students meet the desired Outcomes achievement, and the number of places within the curriculum that Outcomes can be measured and evaluated.

v. Modifications are made to course components to improve student learning on topics corresponding to any problematic Outcomes.

Figure 4-1 summarizes the outcomes assessment process.

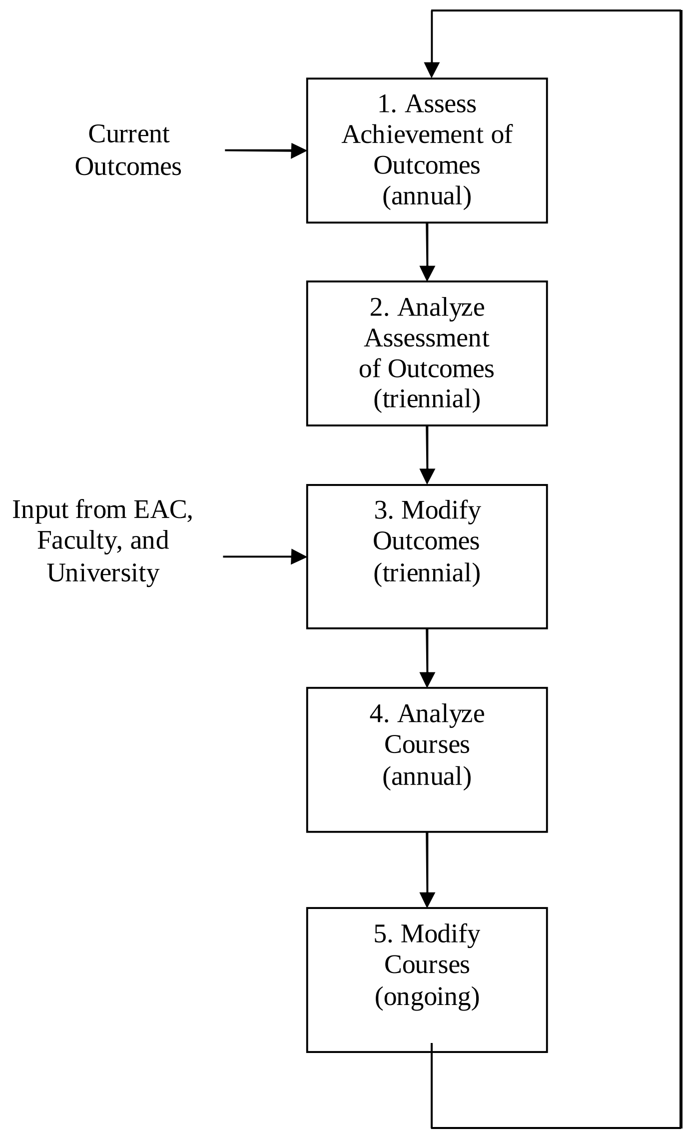

Figure 4-1. Outcomes Assessment and Periodic Evaluation Process

2. The frequency with which these assessment processes are carried out

The assessment process occurs on an annual basis, with a triennial evaluation period. Outcomes Indicator Course data are collected each semester (fall and spring), and the assessment summary and faculty analysis occur during the summer and early in the fall at the annual Faculty Retreat and the annual External Advisory Council meeting. Formal data observation and trend analysis occurs on a three-year basis, or potentially more or less often depending upon changes to the curriculum, instructors, or other adjustments. The formal assessment and evaluation occurs approximately triennially for the purposes of examining trends and changes.

3. The expected level of attainment for each of the student outcomes

Our Outcomes Evaluation process uses a 70% score as the level at which student achievement of the Outcome is deemed unsatisfactory. If the Outcomes score is 70% or higher, the performance is judged to be satisfactory, although continuous improvement and monitoring is applicable in any case. Of equal consideration is any trend in Outcomes scores from year to year, especially in the case of a declining Outcome score. The 70% level was chosen as a guideline corresponding to a C- letter grade, which suited the faculty and the External Advisory Council regarding the level at which urgent steps would need to be taken to correct a deficiency in that student Outcome.

4. Summaries of the results of the evaluation process and an analysis illustrating the extent to which each of the student outcomes is being attained

Figure 4-2 shows the cumulative outcomes scores for data collected in the preceding academic year (2014-2015).

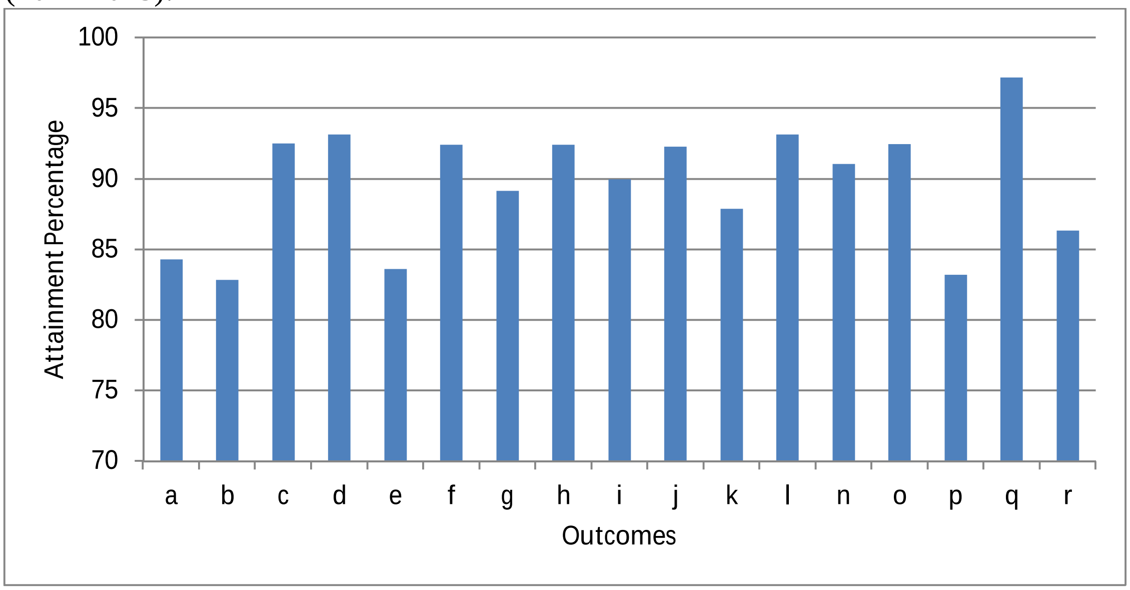

Figure 4-2: Program Outcomes for Electrical Engineering, AY15

An attainment level of 70% or less triggers immediate action, and we see from these data that none of the scores for EE Outcomes are at or below this level. In fact, all of the attainment scores are greater than 80%. The lowest specific EE Outcomes attainment score is 83% for Outcome b (An ability to design and conduct experiments, as well as analyze and interpret data). Evaluation of specific Outcome performance is discussed later in this section.

As noted in the process description above, it has been our practice to observe trends in Outcomes Attainment scores, as our faculty members feel that absolute "snapshot" scores may contain less information about the health of the program than a careful observation of trends. If certain Outcomes exhibit a decline over time, the faculty are interested in determining what might account for the decline, and then act to correct the deficiency rather than waiting for the 70% trigger point. Analysis of Outcomes scores and linear estimated trends over 13 years (2002, 2005, 2008, 2011, 2015) is shown in Figure 4-3.

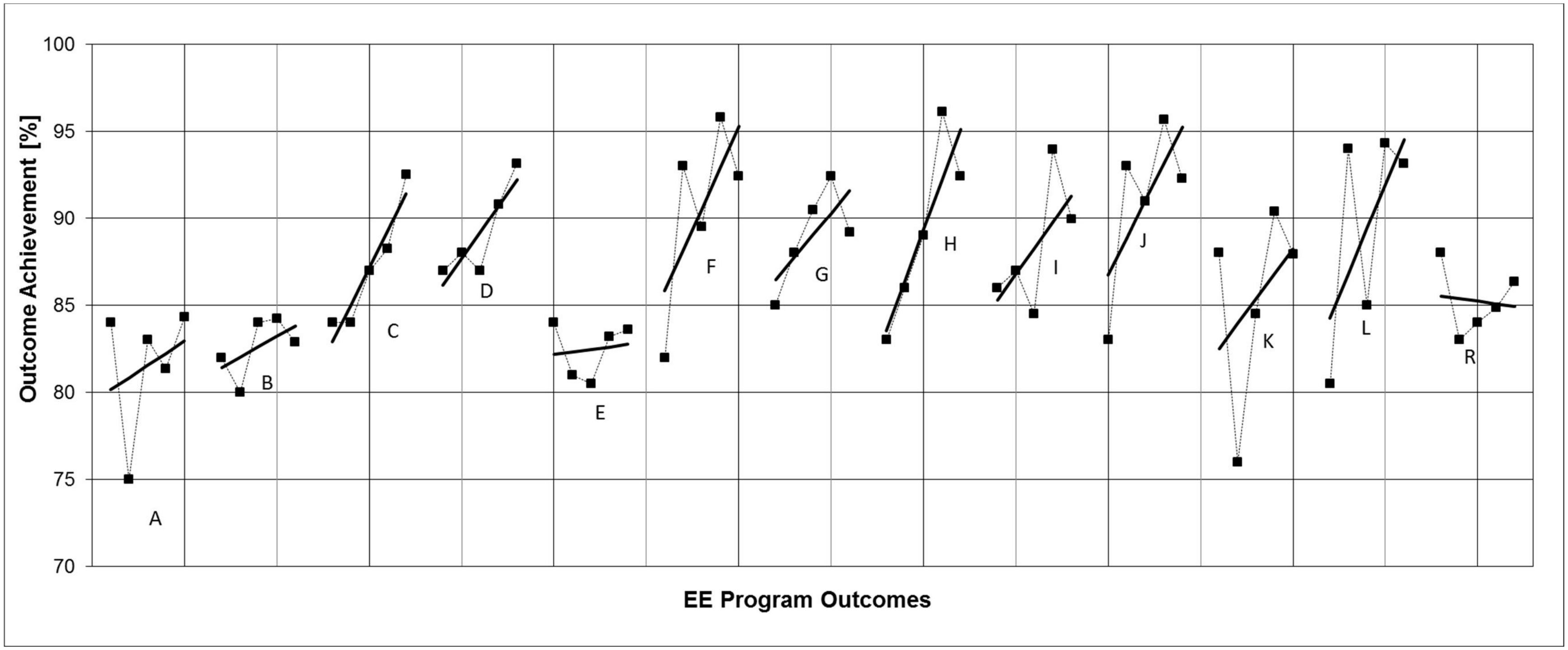

Figure 4-3: Outcome Attainment Trends for the EE Program, 2002, 2005, 2008, 2011, 2015

In Figure 4-3 we see satisfactorily rising performance trends for all Outcomes except for outcome r (*An ability to analyze and synthesize electronic devices and electrical systems*). For Outcomes a-l we attribute the rising performance levels to the increasing awareness of our instructors to the Outcomes and to finding the best ways to include Outcome-relevant material in the courses and the assessment process.

In evaluating these data, we wish to know if the fluctuations and trends—particularly the downward trend—are due simply to the expected semester-to-semester differences in instructor and student cohort, or if the trends appear to be changing in any systematic way. Accordingly, the faculty and the External Advisory Council review these charts and discuss the implications of the provided information.

Looking specifically at Outcome r, the faculty noted that while the linear regression slope is downward, the actual trajectory appears to be positive year-over-year, except for the decline between 2002 and 2005. Outcome r is based on Outcomes Indicator data from EELE 308 Signals and Systems, EELE 317 Electronics, and EELE 488/489 Capstones. The faculty evaluation is that changes and improvements made to the sophomore-level classes EELE 201 and EELE 203 have resulted in better circuits and systems performance in the junior-level courses in recent years, and that the trend since 2005 is a favorable indicator.

From these results we conclude that four of our Outcomes, namely h, i, j, and l, have been and continue to be relatively difficult to measure. These Outcomes refer to global and societal context (h), lifelong learning (i), contemporary issues (j), and project management (l).
We continue to use the Indicator Courses for assessing specific Outcomes. We are also working with the faculty to increase data collection over all Outcomes, and particularly to seek more Outcome-related course content and objective measures for h, i, j, and l.

5. How the results are documented and maintained

Outcomes information is collected each semester for Outcomes Indicator Courses using a spreadsheet submitted by the course instructor. The spreadsheet includes the grading information for each element associated with the specified Outcome, and there is a breakdown by student major (Electrical Engineering, Computer Engineering, Other). This raw information is saved electronically as part of the departmental email conversation threads concerning ABET-related topics.

The raw information from each Outcomes Indicator Course is then copied into a working spreadsheet that contains the information from the multiple classes that contribute to the overall attainment score. The data are combined as averages and then listed as the numerical performance percentage for the corresponding Outcome. The overall attainment spreadsheet has columns for each triennial evaluation, and the data are used to produce the graphical depictions used in Figure 4-2 and Figure 4-3 above.

The historic data are maintained with the other ABET-related information in the department's electronic archives.

The updated Outcomes assessment and evaluation information for 2008-2009 will be available during the ABET visit in the fall of 2009.

B. Continuous Improvement

Describe how the results of evaluation processes for the student outcomes and any other available information have been systematically used as input in the continuous improvement of the program. Describe the results of any changes (whether or not effective) in those cases where re-assessment of the results has been completed. Indicate any significant future program improvement plans based upon recent evaluations. Provide a brief rationale for each of these planned changes.

The primary impetus for program improvement comes from the ECE Faculty. The faculty members are dedicated to continuous monitoring and improvement of the program, and use the Objectives and Outcomes processes for assessment.

Our departmental Undergraduate Program Committee (UPC) plays a critical role in discussing curricular issues and evaluating areas in need of improvement. After in-depth review and evaluation, the UPC brings the issues to the attention of the entire faculty for discussion and making a final decision.

The faculty use a variety of information sources to guide their work on the curriculum. These include:

- Input directly from our students, both formal and informal responses, regarding course content, laboratory experience, teaching methods, and articulation of prerequisites.
- External Advisory Council recommendations
- Recruiters/employers survey and comments
- Recent alumni survey
- Student placement information
- Student performance on the FE Exam (required of all students)
- Range of assignments for internships
- Number of students participating in IEEE and other continuing education opportunities.
- Electrical and Computer Engineering Department Heads Association (ECEDHA) meetings and other trend assessments
- National initiatives, such as the "Engineer of 2020"
- Reports from the Carnegie Foundation, NSF, ASEE Committees, etc.
- Campus and College initiatives, such as the CORE 2.0 (general education) curriculum, common course numbering, student retention and support, etc.
- Material from relevant educational journals such as “Teaching Professor”, "Journal of Engineering Education," "IEEE Transactions on Education," etc.

The faculty and staff also engage in a formal annual review process based on current achievements, professional goals, and continuous self-improvement processes. Faculty address specific questions such as:

- *Of which two specific achievements are you most proud among your many accomplishments this past year? Why?*
- *Which areas of your professional work are most in need of improvement?*
- *Summarize your accomplishments toward your short-term and long-term goals as stated on last year's self-evaluation.*

- *Please share your short-term goals (things to accomplish during the current year).*
- *Please summarize your longer term goals (e.g., things you plan to accomplish over the next two or three years) in teaching, research, and service.*

Among the review outcomes are often discussion of new course proposals, assignments for laboratory development, and collaboration on targeted curricular funding requests to NSF and other agencies, that all are directed toward program improvement.

Action: **Common Course Numbering in Montana University System**

The Montana University System (MUS) engaged in a state-mandated program to coordinate among the universities to develop and implement a Common Course Numbering (CCN) system across the state. Courses previously designated "EE" became courses in the "EELE" rubric, with course numbers adjusted to reflect the CCN coordination.

Rationale/Results: The intent of the program was to make it easier for a student taking a course from one branch of the MUS to transfer to another branch with automatic acceptance of credits. This process entailed eliminating the former curricular designation rubrics and creating new rubrics that would be common across the MUS. A positive side effect of the CCN process was that faculty from our sister institution, Montana Tech (Butte, Montana), and our Montana State University faculty coordinated with each other on the learning outcomes and general curricular structure for the EE program offered in Butte and our EE program offered in Bozeman.

Action: **Change to the required introductory computer programming course in the EE curriculum**

Since about 2008, our Computer Science department has chosen to use Java as the language introduced in the Introduction to Programming course. ECE Faculty have been concerned that Java is not providing sufficient background for EE students who need strong skills in a procedural language (rather than object-oriented language) for embedded systems.

Rationale/Results: The ECE faculty discussed the matter with the CS faculty, and came to the conclusion that EE students should take CSCI 112 C Programming instead of CSCI 111 Java. However, CSCI 112 has a prerequisite of either CSCI 111, or that the student has some knowledge of programming principles. This resulted in a corresponding change to EELE 101 (see below) to include the introductory programming material so that EE students would be prepared to go directly into CSCI 112 without necessarily having CSCI 111. Results to date have been favorable.

Action: **Change to the introductory EE course EELE 101 Introduction to Electrical Fundamentals**

A decade ago EELE 101 was a 1-credit, lab-only course intended to be an easy "gee whiz" introduction to electrical engineering. In 2004, the course was modified to have a lecture section in addition to the lab, and the lab introduced a custom autonomous robot project. After considerable discussion by the faculty about the appropriate computer programming introduction (see above), EELE 101 was modified in Spring 2013 to have a 3-credit format: a lecture, a lab, and a newly conceived recitation section each week to provide a beginner's introduction to C language programming.

Rationale/Results: The change to EELE 101 has been well received by the faculty and the students. The laboratory and recitation work is now largely based on the Freescale Cup autonomous car kit, which is a microprocessor-based electric vehicle that each student builds, programs, and tests as part of the course. Students who have taken EELE 101 have gone directly into the second programming course offered by the CS Department and have been well prepared for success.

Action: **Changes to the senior capstone design sequence**

The Capstone Design experience is widely considered to be among the key features of undergraduate engineering education. In the early 2000s, the EE program contained a two-semester sequence of seminar courses to provide the Capstone. The first semester was a general introduction to design principles and teamwork, and the students built some simple demonstration projects. The second semester comprised the open-ended, small-team design project. In about 2008, the design sequence was changed to have the first course be EGEN 310, an interdisciplinary design introduction taught to all students in the College of Engineering, followed by the second semester of the open-ended design project. Faculty, students, and the External Advisory Council were not pleased with the limited scope of capstone projects that could be accomplished in only a single semester. Thus, a change was made in Fall 2011 to make the capstone sequence consist of three consecutive semesters: EGEN 310 Multidisciplinary Design (3cr), then EELE 488 Electrical Engineering Design I (2 cr), followed by EELE 489 Electrical Engineering Design II (2 cr). Later, the Design II course was increased from 2 cr to 3 cr to reflect the expected amount of time students would be working on finishing their design projects.

Rationale/Results: The change to a three-semester capstone sequence is going well, based on feedback from the students, assessment of student performance, and comments received from our External Advisory Council, employers, alumni, and members of the public. An additional feature of the revised sequence is that our EE students are enabled to choose multidisciplinary capstone projects involving students from Mechanical Engineering, Computer Science, and other programs that have a corresponding time line. We have arranged that the EE capstone seminar meeting time matches the Mechanical Engineering capstone seminar time, so students have fewer logistical impediments compared to the situation before these changes were made.

Action: **Changes to the slate of required courses in the EE program**

Faculty, students, and External Advisory Council members have discussed the importance of allowing more flexibility and electives into the EE program requirements, while still maintaining a strong program in the traditional fundamentals. Increasingly, we are seeing student interest and graduates working in fields related to biology, alternative energy, chemical processes, entrepreneurial start-ups, etc., that can benefit from academic preparation in areas outside of the EE field per se. In order to address these desires, the faculty have worked to increase the number of credits assigned to professional electives and reduce somewhat the number of credits in required courses that every EE student must take.

Rationale/Results: The adjustments have been small, but the acceptance by students, faculty, and the companies that hire our graduates has been very good. Starting in 2007, the course in Engineering Economics was switched from being required to being an elective. Many students now choose to take a course in entrepreneurship instead of the traditional Engineering Econ course. And in 2012, the decision was made to move Engineering Statics from being a required course to being an elective. There was some concern that the lack of required Engineering Econ and Engineering Statics would lead to poor performance by EE students on the required FE exam, but performance results on the FE have not revealed any change attributable to these adjustments.

Action: **Changes to reduce curricular bottlenecks and reduce time-to-graduation**

From 2009-2012, the ECE faculty reviewed the course Outcomes and overall curricular progress of our students and determined that a faculty subcommittee should examine ways to create curricular "threads" that would give better guidance to students about course choices and electives. Simultaneously, there arose a campus-wide emphasis on decreasing the time to graduation, which for many university programs the average is well over 4 years even though the curricular guides show a 4-year plan.

A variety of different options and formulations were discussed, and after considerable debate including our faculty, students, External Advisory Council members, and other colleagues across the campus, we developed a plan that considered the precise sequence of courses and electives to eliminate "orphan" credits and to improve the flexibility of typical schedules.

Rationale/Results: Overall, this process reduced the EE program from 128 credits to 125 credits, while increasing the number of professional electives to 18 credits (9 credits must be EELE, 6 credits must be outside EELE, and 3 credits can be a wild card). Approval and refinement was completed in the Fall of 2012 and rolled out sequentially by semester beginning in the Spring of 2013. Our current evidence is that these changes have increased student awareness of the importance of staying on track to achieve timely degree completion, and overall that the changes have simplified the advising and student registration process.

Action: **Curricular consistency on lecture and lab configuration**

For a variety of reasons, many of them simply historical tradition, the EE curriculum included several courses in which the lecture and the laboratory components were combined into a single course number, and several courses in which the lecture and the corresponding laboratory were taught under different course numbers. This disparity led to some confusion by the students, and needless complexity in cases where a student had completed the lecture and needed the lab, but the lab was not necessarily offered every semester. The faculty discussed the pros and cons of making a consistency change, and decided to move toward embedding the required lab components into the corresponding lecture courses.

Rationale/Results: The combination of EELE 261+EELE 262 into EELE 261, combination of EELE 445+EELE 446 into EELE 445, and EELE 466+EELE 467 into EELE 466, has been accomplished and is working well. No additional changes or reconsideration appears to be necessary at this time.

Action: **Updates and improvements to campus academic advising tools**

Beginning in 2002, the ECE Department utilized a custom-designed and implemented "Automated Advising System," created and maintained by ECE faculty member Dr. Steven Shaw. The system used the official university records database maintained by the registrar and created a checklist and flow sheet for each student in the program, showing the student's current progress toward degree. In 2012 the University purchased a commercial software module called DegreeWorks that provided an official and reasonably comprehensive presentation of degree progress and degree audit at the time of graduation. The DegreeWorks system is centrally managed and has active staff who perform the day-to-day maintenance functions of the system.

Rationale/Results: The ECE Department switched from its custom advising software to the campus-wide DegreeWorks system in the spring of 2013, and has found the system to be very useful and effective for our student program advising.

The DegreeWorks system has had most of its bugs and peculiarities worked out, and students and their faculty advisors use it exclusively for degree progress discussions during advising sessions. The campus has also moved forward on inclusion of semester-by-semester plans and mandatory electronic degree audit at the time of graduation. New features for ease-of-use are planned, but overall the system is working well for our advising purposes.

Ongoing
Action: **Experimental work with online education and hybrid web-enhanced education**

Among the long-term goals of the College of Engineering and of the ECE Department are expanding the access and influence of our academic and research programs to citizens across the state of Montana. Electronic dissemination and online education make sense in a geographically large and sparsely populated state, but the Department has limited experience in and resources for conducting online courses in the EE program.

Another issue is that some students need or want to begin their studies at a regional college or university, then transfer to our EE Program to complete a degree later. However, the sequence of pre-requisites in the EE program makes it difficult for a student to take two years of courses at a local college and then try to complete an EE degree in less than 3-4 years after transferring. Some means to allow the remote students to take a few key lower-division EE courses online would help reduce the total calendar time to degree.

Rationale/Results: During the spring 2009 semester, Prof. Jim Becker was assigned to teach an experimental offering of the introductory circuits class, EE 206 (now EELE 201), to students enrolled at Montana State University-Billings (approximately 100 miles east of Bozeman), using the Desire To Learn (D2L) web-based system. The laboratory portion of the course was taught by a qualified instructor on-site in Billings, so the students received the lecture material, homework, and exams via D2L and the concurrent hands-on laboratory experiments "live" in Billings. The experimental offering worked well, but the Billings campus has been unable to provide a sufficiently large stream of students to make the effort sustainable.

Since the summer of 2012, Prof. Becker has been assigned to teach our second circuits class, EELE 203, in a hybrid format with online (D2L) lecture material and live-taught labs and exams. Student performance in the course is comparable to students who take the class as a regular lecture+lab during the spring semester, and students who go on to take the following courses in the fall are also doing as well as the students who took the regular class. The course is gaining a sufficient number of students that we intend to continue offering it for the foreseeable future.

In the summer of 2015, Prof. Brock LaMeres was assigned to teach an experimental version of the digital systems introduction EELE 261 using an entirely online format. Students check-out a laboratory demonstration board and perform and demonstrate the lab experiments using the USB-attached boards attached to their own computers at home. We will examine the performance results at the end of the summer and consider the advantages and disadvantages of this instructional format.

Both Prof. Jim Becker and Prof. Brock LaMeres have NSF education funding that is enabling this work, and both professors recently had peer-reviewed articles published in IEEE Transactions on Education.

Ongoing
Action: **Control Systems instructional lab format**

In 2010, a control systems laboratory was created to provide hands-on experience to go with the EELE 321 Control Systems lecture course. The course with lab was offered yearly 2010-2013, but the instructor and the students reported that the lab was not accomplishing its desired learning outcomes because by the time the lecture content provided sufficient theoretical background for meaningful laboratory experiments, most of the semester was consumed and therefore the initial weeks of the lab were not being used in a fruitful manner. The faculty discussed a proposal to eliminate the lab from EELE 321 and move the lab experience instead into the advanced controls course, EELE 422.

Rationale/Results: The laboratory portion of EELE 321 was removed in 2014, and a test offering of the standalone advanced lab was provided in the fall of that year. The test offering was sufficiently successful that we anticipate the change to the lab configuration to be made permanent in the next year or so, based on instructor availability.

<u>Ongoing</u>
<u>Action</u>: Targeted recruiting of women into the ECE Programs

The percentage of female students in the EE Program remains in the 10-15% range. This is consistent with national statistics, but the reasons for the sustained low percentage of women and remedies are not yet well understood. The ECE Department has been engaged with the National Council of Women in Technology (NCWIT), Engineer Your Life (www.engineeryourlife.org), Engineer Girl (http://www.engineergirl.org/) and with the National Academy of Engineering CASEE Engineering Equity Extension Service (EEES) program (http://www.nae.edu/?ID=13891).

<u>Rationale</u>: The broad impact and diversity aims of Montana State University and the ECE Department imply the need to make all potential students aware of opportunities in electrical and computer engineering. Our current enrollment includes a low percentage of women and a low percentage of other nationally underrepresented groups. The Department is looking for ways to leverage our limited time and resources by identifying best practices and strong existing organizations with which to partner.

<u>Status</u>: The Department is engaged this year as a NCWIT school, and we have hosted a visit by the program manager. In recent years we have also received and distributed recruiting material from Engineering Your Life to 250 middle school girls who participated in a campus science and engineering outreach activity this spring. We also include recruiting links from our web site. Another project funded by NAE CASEE EEES allowed us to mail information about engineering opportunities to every science and math teacher in middle schools and high schools in Montana.

<u>Ongoing</u>
<u>Action</u>: Expanded FPGA coverage

In response to industry trends and the availability of practical development boards and support software, the Department now includes field programmable gate array (FPGA) material in the digital systems portion of our curriculum.

<u>Rationale</u>: The faculty have observed the long-term trend away from full custom semiconductor design and discrete glue logic toward semi-custom design based on (FPGAs) and other reconfigurable systems. This trend has been confirmed by industrial contacts and the Advisory Council. Thus, since 2004 the upper-division courses in the computer design and digital systems area now include exercises and lab experiments involving FPGA-based systems. The digital design courses EELE 367 Logic Design, EELE 466 Computational Computer Design, and other digital electives, now let the students gain experience with hardware description languages and FPGA implementation concepts.

<u>Status</u>: The current FPGA exposure uses VHDL as the description language and Altera FPGA hardware. Students use FPGA systems in the advanced digital systems courses, and this expansion is likely to continue as the industry trends evolve.

C. *Additional Information*

Copies of any of the assessment instruments or materials referenced in 4.A. and 4.B must be available for review at the time of the visit. Other information such as minutes from meetings where the assessment results were evaluated and where recommendations for action were made could also be included.

Documentation of the assessment material, email messages, meeting minutes regarding curriculum and advising issues, and related continuous improvement material and evidence will be available as a file repository (hardcopy and scanned pdf) for the review team visit.

FE Exam Assessment

All students in the EE program are required to take the FE Exam prior to receiving their degree. Students are not required to pass the exam, but they must make a full and reasonable effort to do so. We monitor the pass rate on the FE in comparison with the national pass rate and the pass rate for Carnegie 1 research institutions, of which Montana State University is a member. The recent summary is shown in Table 4-1.

In recent years (2009-present) the pass rate for MSU EE students is 84%, compared to the Carnegie 1 RU/VH rate of 76%. While at many other institutions the exam is optional and students self-select to take it, the FE exam is mandatory for our students, so we feel that the relatively high pass rate from our program is additional evidence that our students are receiving good depth and breadth in the EE program. Moreover, the EE students receive proportionately less formal curricular exposure to traditional engineering topics covered on the exam such as statics, materials, and thermodynamics, so their pass rate on the FE is notable because it indicates that the students are able to prepare for the exam in a meaningful, productive manner.

Table 4-1 FE Discipline Specific Exam Results, EE Program

	MSU				National Average				Carnegie 1 RU/VH			
Exam Date	Taking	Passed	Failed	Pass Rate	Taking	Passed	Failed	Pass Rate	Taking	Passed	Failed	Pass Rate
fl03	8	6	2	75%	645	470	175	73%	324	254	70	78%
sp04	18	17	1	94%	1,258	969	289	77%	580	465	115	80%
fl04	10	9	1	90%	584	439	145	75%	301	236	65	78%
sp05	23	19	4	83%	1,096	824	272	75%	454	350	104	77%
fl05	9	7	2	78%	631	432	199	68%	322	244	78	76%
sp06	15	14	1	93%	1,193	840	353	70%	468	357	111	76%
fl06	9	9	0	100%	658	448	210	68%	306	222	84	73%
sp07	21	17	4	81%	1,101	767	334	70%	471	353	118	75%
fl07	9	9	0	100%	681	475	206	70%	282	215	67	76%
sp08	12	10	2	83%	1,199	909	290	76%	433	348	85	80%
fl08	4	4	0	100%	70	47	23	67%	30	23	7	77%
sp09	24	22	2	92%	1,184	867	317	73%	292	218	74	75%
fl09	6	5	1	83%	689	481	208	70%	187	142	45	76%
sp10	15	14	1	93%	1,224	886	338	72%	306	238	68	78%
fl10	13	8	5	62%	682	456	226	67%	183	137	46	75%
sp11	18	13	5	72%	1,249	869	380	70%	268	189	79	71%
fl11	4	4	0	100%	730	505	225	69%	190	138	52	73%
sp12	16	15	1	94%	1,275	990	285	78%	256	200	56	78%
fl12	6	5	1	83%	758	464	294	61%	182	125	57	69%
sp13	21	17	4	81%	1,472	1,060	412	72%	286	214	72	75%
fl13	10	9	1	90%	809	530	279	66%	218	153	65	70%
sp14	8	8	0	100%					672	550	122	82%
fl14	12	9	3	75%					595	462	133	78%
Total	291	250	41	86%	19,188	13,728	5,460	72%	7,606	5,833	1,773	77%
Recent (since 2009)	153	129	24	84%	10,072	7,108	2,964	71%	3,635	2,766	869	76%