Electrical Engineering Undergraduate Curriculum Committee Report
Chair: Andrea Goldsmith;

Executive Summary
The undergraduate curriculum committee was formed in the fall of 2002 to execute a comprehensive evaluation of the Electrical Engineering (EE) undergraduate program. The goal was to make the EE major more rewarding, relevant, and fun by developing a core set of required classes in key areas of EE, with strong specialty sequences to follow each core area. Other goals included reducing the prerequisite chain for many classes, adding more flexibility, and facilitating a quarter or two in the overseas program. The result was a streamlined set of six core courses in three areas: circuits (EE101AB), signal processing and linear systems (EE102AB), and digital systems (EE108AB), which were implemented in the 03/04 academic year. These classes are all 4 units and include a lab component. A new sophomore course on the physics of EE (EE41) was developed as an alternative to the electromagnetic waves requirement (EE140). The device courses (EE 111-EE 113) and digital architecture course (EE182) were eliminated as requirements with some of their material integrated into EE41, EE101B, and EE108AB.

Subsequent to these changes, the committee was chartered with evaluating the rollout of the new core, evaluating and revising the specialty sequences to complement the new core, considering possibly revisions to lower division requirements, expanding the course offerings for capstone design classes, and evaluating the CSE major. This report documents the committee’s recommendations in each of these areas. All recommendations have been approved by the AAC and will be in place for the 2006-2007 academic year.

Curriculum Changes and Feedback:
Most courses in the new core have been taught three consecutive years. Students indicate that the new core provides good preparation for more advanced courses, although there was some concern about this issue for the EE101AB series. Students also expressed concern about the consistency, workload, scheduling, and some lab issues in the core (a summary of specific comments can be found in Appendix A). EE Freshman Seminars, offered every year since 2003, are very popular with both students and faculty. The math courses offered through the CME department (CME100/102/104) as an alternative to the traditional math series requirement (MA51/52/53) are being taken advantage of, and the students generally find this alternative more relevant to their engineering classes. Based on our recommendation, Physics 55 (light and heat) has been removed as a requirement for the major, and of the 45 math/science required units, 12 must be in science, and 3 may be in EE (except EE178). The Engineering Electromagnetics requirement (EE141) was also changed to an EE physics requirement that is satisfied with either EE141 or EE41. ENGR40 is no longer an EE requirement although it can be taken to satisfy one of the engineering fundamentals requirements. Most EE students continue to take it as their first EE course: it is popular and viewed as an attractor course for EE, at least by some students. To increase flexibility and maintain core symmetry, the analog design lab EE122 has been removed as an EE requirement. Several new courses in existing depth sequences (e.g. EE109 in digital systems and EE116 in electronics) were added to the EE curriculum to compensate for material removed from the old EE core. A new specialty sequence in solid state and photonic devices was also added. The committee developed a set of recommendations for capstone design courses to help facilitate development of such courses, and the AAC then added several existing courses (EE168, EE262, EE265) and a new photonics course (EE134) to the list of capstone design class options. The committee also recommended that EE not participate in the CSE major, based on lack of faculty interest. The major will continue to be offered by the school. It should be noted that the EE undergraduate enrollment has shown a significant increase in the last few years, with enrollment in the 04/05 and 05/06 academic years (around 125 students) significantly higher than at any time over the last decade.

Recommendations for Ongoing Oversight:
One person on the AAC should have ongoing responsibility for monitoring and resolving undergraduate issues. We have identified 11 areas that require ongoing oversight (See Section 6 for more details): evaluation of core courses; offering of freshman seminars; updates to specialty sequences; expansion of capstone design courses; expansion of introductory design courses; course scheduling; updating the undergraduate handbook, facilitating study abroad; soliciting student feedback; increasing interaction with faculty and student diversity; full curriculum evaluation every 5 years. We also recommend that the labs of the core classes be evaluated within the next two years.
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1. An Overview of the Revised Undergraduate Curriculum

A summary of the current electrical engineering (EE) undergraduate curriculum is shown in the flowchart of Figure 1. The main goals of the curriculum are as follows:

- “Hook” students into EE early on.
- Make lower division requirements more relevant to the major.
- Make core classes parallel and complementary, with labs for each class.
- Offer comprehensive specialty sequences and multiple options for capstone design courses.
- Make the EE major more rewarding, relevant, and fun.

To fulfill these goals, we recommended the following changes to the undergraduate curriculum:

- Add freshman seminars to generate interest in the EE major early on.
- Increase flexibility in the lower division requirements.
- Increase flexibility in the Electromagnetics requirement.
- Build a set of three 2-quarter required core classes that can be taken in any order.
- Improve the specialty sequences offered around the core.
- Significantly expand the number and type of capstone design courses.

We now offer 3-5 EE freshman seminar courses each year, so that students can get exposed to the EE major before or while taking their lower division required courses. Most freshmen interested in EE have already taken basic calculus (Math 41 and 42) in high school. Thus, EE majors typically take the required Math 51/52/53 series (calculus, vector calculus, and linear algebra) in their freshman year, and the required Physics 41/43 series (statics and electromagnetics) in the freshman or sophomore year. Many students complain that these math and physics classes do not seem to have much relevance to EE. There is
an alternative set of math courses, CME100/102/104, taught through the mathematical and computational science (CME) department in the school of engineering (SOE) that satisfy the lower division math requirements with a greater emphasis on engineering, and students should be informed of this option. The committee recommended that the physics requirement no longer includes Physics 55 (light and heat), which was not a prerequisite for any EE class. Instead we recommended that this class be replaced by a more general science requirement (which can still be satisfied by Physics 55), since courses in biology, chemistry, and other sciences are becoming highly relevant to some areas of EE.

The committee recommended that ENGR40 (Introduction to Electronics) no longer be required for the EE major; instead our requirement should be consistent with the SOE requirement of two engineering fundamentals plus E70X or CS106B. ENGR40 will continue to be recommended as a prerequisite to the core circuits class (EE101A), as a preferred means to satisfy the engineering fundamentals requirement, and as a good introduction to some aspects of EE. We also recommended that the Electromagnetics requirement be satisfied by either EE141 or EE41 (a lower division class with a broader and higher-level focus than EE141). Students that elect to use EE41 to satisfy the Electromagnetics requirement may also take this class their freshman or sophomore year, and use EE141 as part of the fields and waves specialty sequence.

Most student will take at least one and possible all of the 2-quarter core sequences – circuits (EE101AB), signal processing and linear systems (EE102AB), and digital systems (EE108AB) – their sophomore year. This allows the students to get a broad overview of EE fairly quickly. It will also free up the junior and senior years for specialization and the capstone design course, as well as the option for 1-2 quarters abroad in the overseas program.

All core courses include a lab component. The importance of both experimental and software simulation experience motivated incorporating labs into all core courses. In addition, a 1-unit optional course on circuit simulation, EE114, has been added to help students bridge the gap between the relatively simple circuit simulation in EE101AB and the simulations in upper division circuit design courses.

There are currently seven specialty sequences for undergraduates: circuits and devices, communications and signal processing, computer hardware, computer software, control systems, fields and waves, and solid state and photonic devices. The specialty sequences consist of 3 courses related to one of these areas. These specialty sequences feed into the capstone design class, whose goal is to synthesize knowledge from the specialty area based on an open-ended project. However, students are not restricted to take a capstone design course coupled to their specialty area, and in the past there were many specialty sequences without a related capstone design class. This weakness was addressed by significantly expanding the number of capstone design courses, as discussed in more detail in Section 2.2.

2 Curriculum Components

2.1 Freshman Seminars

Freshman seminars were initiated campus-wide in the 1980s by president Gerhard Caspar as part of a broad initiative to improve undergraduate education. The purpose of these courses is to introduce freshman (and sophomores) to exciting topics within a given discipline area through a small group setting working closely with faculty. Caspar offered additional billets and funding to departments as an incentive to initiate such seminars, and most departments took advantage of the opportunity. These seminars are extremely popular and also serve as a recruiting tool for many departments, including those within the SOE. EE chose not to participate in the freshman seminar program, partly due to difficulty in staffing its required undergraduate classes along with its large MS program. When the EE core was revised, it was also recommended that freshman seminars be added to enhance the overall curriculum.
The department offered freshman seminars for the first time in the 04/05 academic year, including “How cyberspace works” by Bernd Girod, “Things about stuff” by Tom Lee, and “How musical instruments work” by David Miller. Freshman seminars for the 05/06 academic year included "From science fiction to science" by Jelena Vuckovic, “The art and science of engineering design” co-taught by Andrea Goldsmith and My Le, “Engineering the micro and nano worlds: from chips to genes” by Fabian Pease, and a repeat of Tom Lee’s “Things about stuff”. The seminars have generally been oversubscribed, highly rated, and fun. In the 06/07 academic year five seminars will be offered: “The magic of Pi and other mathematical and physical constants” by Nick McKeown, “Hacking stuff” by Peter Peumans, “How the Internet works,” by Fouad Tobagi, “What is nanotechnology?” by H.S. Philip Wong, and a repeat of “How musical instruments work” by David Miller.

The EE freshman seminars have been very rewarding for both students and faculty, have brought additional funding into the department, and are now considered an important component of our undergraduate curriculum. All EE faculty are encouraged to consider offering a freshman seminar every 2-3 years, as long as it does not interfere with coverage of core undergraduate or MS courses. Freshman seminars count towards teaching credit the same as a regular EE course. The AAC will be responsible for soliciting volunteers for introductory seminars and coordinating their approval through the department chair and the university office of freshman and sophomore programs.

Sophomore seminars were not a focus of our committee, as it was felt that there are not enough faculty to cover additional sophomore seminars without sacrificing more critical undergraduate and graduate offerings. These courses also do not count towards regular teaching credit, so there is less faculty incentive to teach them in comparison with freshman seminars.

2.2 Math and Science Requirements

The math and science requirements now include either Math 51/52/53 or CME 100/102/104, Physics 51/53, a total of 12 science units, and a total of 45 combined math and science units, of which 3 can be satisfied by an EE class. We are encouraging students to replace the Math 51/52/53 series with CME 100/102/104, which covers similar material but with more of an engineering focus. While either set of courses satisfies the math requirement, few students are aware of the CME courses or their equivalence to the more traditional math courses. We believe EE students will find these math classes more relevant to their interest in engineering.

The committee recommended to remove light and heat (Physics 55) as a requirement. The minimum science requirement in the EE curriculum remains at 12 units, of which 8 are satisfied by the Physics 51/53 requirement. Thus, students can take any 4 unit science course, including Physics 55, to complete the minimum science requirement. This recommendation was made based on increasing flexibility in the lower division requirements as well as the increasing relevance of science courses such as biology and chemistry to some areas of EE.

We also proposed to increase flexibility in the math and science requirement by allowing 3 of the total 45 math and science units to be satisfied with an EE course. This decision is based on the fact that there are many courses within EE that have a strong math or science basis, and such courses may be more relevant to EE majors than a more general math or science course. However, ABET requires a minimum 45 units of math and science units, and it is not obvious how satisfy the unit total with EE courses. Therefore, the recommendation has not yet been adopted by the AAC, and will be taken up again next year after discussions with ABET during their visit.

2.3 EE Physics Requirement
The EE physics requirement can be satisfied by either EE41 or EE141. EE41 is a lower-division broad introduction to electromagnetism and basic device physics, as well as the importance of these fields in electrical engineering. EE141 is an upper division course focused on a more rigorous treatment of electromagnetism. The enrollment in EE141 has stayed relatively constant even though the course is no longer required. It is too early to see what balance of students will opt for EE41 or EE141 to satisfy this requirement, but the flexibility of both options seemed well received by the students.

2.4 Engineering Fundamentals and Other Requirements

The school imposes engineering fundamentals and other requirements on all majors. To satisfy these requirements, EE majors must take 3 engineering fundamentals courses, one of which must be E70X (programming methodology) and one of which must be outside of EE and CS. Although ENGR40 was removed as a requirement for EE majors, it is still recommended as a prerequisite to EE101AB and as a good introduction to some aspects of the major. ENGR40 is a popular course and it is anticipated that many students will use ENGR40 to partially satisfy the EE fundamentals requirement. Note that ENGR40 is undergoing some substantial changes in the 2006-2007 academic year under the direction of Roger Howe and Simon Wong.

In addition to the SOE requirements, the EE major requires all students to take a technical writing class (E102E), a course on the electrical engineering profession (EE100), and enough additional EE classes to comprise a total of 68 units. There was some discussion in the committee of removing the link between the technical writing class and EE108A, but it was not obvious how to do this. Thus, we have no specific recommendations regarding changes to the writing requirement, except to consider this issue in the future. The committee also felt that the 68 total unit requirement was reasonable, although it is high compared to some other majors in the SOE.

2.5 EE Core Courses

The EE core consists of 6 courses in 3 areas: circuits (EE101AB), signals and systems (EE102AB), and digital systems (EE108AB), described as follows:

Circuits (EE101AB):
This sequence introduces circuit modeling and analysis. Topics in EE101A include creating the models of typical components in electronic circuits; simplifying non-linear models for restricted ranges of operation (small signal model); and using network theory to solve linear and nonlinear circuits under static and dynamic operations. Topics in EE101B include MOS large-signal and small-signal models as well as MOS amplifier design, including DC bias, small signal performance, multistage amplifiers, frequency response, and feedback. The lab component focuses on building the circuit concepts studied in the lectures.

Signal Processing and Linear Systems (EE102AB):
This sequence introduces the concepts and mathematical tools in continuous-time and discrete-time signal processing and linear systems analysis, which are then illustrated with examples from signal processing, communications, and control. EE101A focuses on continuous-time signals, including the mathematical representation of signals and systems, linearity and time-invariance, system impulse and step response, the Fourier series and Fourier transform frequency domain representations, filtering and signal distortion, time/frequency sampling and interpolation, continuous/discrete time signal conversion and quantization, stability and causality in linear systems, Laplace transforms and Bode plots, and feedback and control system design. EE102B focuses on discrete-time signal processing and linear systems analysis, including
discrete-time signal models, continuous-discrete-continuous signal conversion, discrete-time impulse and step response, the Fourier series and Fourier transform frequency domain representations, connections between continuous and discrete time frequency representations, the discrete Fourier transform (DFT) and the fast Fourier transform (FFT), Discrete-time and hybrid linear systems, stability and causality, Z transforms and their connection to Laplace transforms, frequency response of discrete-time systems, and discrete-time control. The lab is Matlab-based, where student use various Matlab functions to implement the models and concepts introduced in the class.

**Digital Systems (EE108AB):**
This course introduces digital circuit, logic, and system design. EE108A includes digital representation of information, CMOS logic circuits, combinational logic design, logic building blocks, idioms, and structured design, sequential logic design and timing analysis, clocks and synchronization, finite state machines, microcode control, digital system design, and control and datapath partitioning. EE108B focuses on the design of processor-based digital systems, including instruction sets, addressing modes, and data types, assembly language programming, low level data structures, introduction to operating systems and compilers, processor microarchitecture, microprogramming, pipelining, memory systems and caches, input/output, interrupts, buses and DMA, system design implementation alternatives, and software/hardware tradeoffs. The lab involves design implementation using Xilinx ISE software, simulation using Modelsim, and testing on Xilinx Virtex-II Pro XC2VP30 FPGA boards. Labs lead students to interface with SDRAM, VGA output and audio output.

All of the core classes have a laboratory component, although EE101AB and 108AB have a more traditional lab whereas the EE102AB lab is software-based. There was some concern about the workload associated with some of the more open-ended lab projects, and this should be periodically monitored. In fact, a general evaluation of the laboratories is recommended since the laboratory in EE102AB was not part of the previous core and the EE101AB and EE108AB labs are substantially different from the labs in the previous core. Insuring a good laboratory experience along with the core material is critical, thus we recommend that the lab components of the core be evaluated within the next 2 years to identify any flaws and address them.

### 2.6 Specialty Sequences
EE Majors are required to complete 3 classes in one of the specialty sequences listed below. This requirement insures that student obtain some depth within a given area of EE. The main challenge in the specialty sequence requirements is keeping the list up to date, and making sure the specialty sequences follow naturally from the core courses. Material that was eliminated from the core has been added to some of the specialty sequences. In particular, the semiconductor device material that was previously required is now covered in EE116.

<table>
<thead>
<tr>
<th>Specialty Sequence</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields and Waves</td>
<td>134,141,142,144,241,246,247,252,256</td>
</tr>
<tr>
<td>Circuits and Devices</td>
<td>116,133,212,214,215,216,271</td>
</tr>
<tr>
<td>Signal Processing and Communications</td>
<td>133,168,179,261,263,264 or 265,268,276,278,279</td>
</tr>
<tr>
<td>Computer Hardware</td>
<td>CS107,109,271,273,282</td>
</tr>
<tr>
<td>Computer Software</td>
<td>CS107,CS108,CS194,284 or CS244A</td>
</tr>
</tbody>
</table>

Table 1: Courses for Specialty Sequences (EE courses unless otherwise indicated)

### 2.7 Introductory Design Courses and EE122
The committee has removed EE122, the analog design laboratory, as a requirement for all EE undergraduates. EE122 is a very popular course, and is one of the most open-ended design courses in the EE curriculum. Thus, it is an important and valuable class for us to offer. However, EE122 is not in the category of a capstone design course: while some students take it in their senior year and do very elaborate projects, other students take it right after ENGR40, and do much simpler projects that would not fall in the category of a capstone design. This flexibility in allowing students to choose the depth and area of their design project is a great strength of the course. However, it makes EE122 somewhat of an anomaly, as similar courses don’t exist in the other core areas. On some level EE122 could be viewed as an introduction to design. Our undergraduates would greatly benefit from this type of introductory design course in their specialty area, and the committee strongly encourages the development of such courses in the other EE core areas (signal processing and linear systems and digital systems). Since such courses don’t exist, we did not think it was appropriate to require all students to take an introductory design course in analog circuits in addition to a capstone design class – this would be inconsistent with the symmetry of required classes in core areas that all students must take. If introductory design courses were to be offered in all core areas sometime in the future, then perhaps the question of whether students should be required to take such a course could be revisited.

### 2.8 Capstone Design Courses

The number and type of courses satisfying the capstone design requirement was somewhat limited in the past, and many students took a capstone design class that had little relation to their specialty sequence. To address this problem, the committee first developed a set of guidelines that capstone design classes should satisfy (see Appendix B). The committee then did a thorough evaluation of existing courses, and found many that satisfied the capstone design guidelines. The committee also solicited the development of some new capstone design courses. We then recommended that these courses be added to the list of classes satisfying the capstone design requirement and this was approved by the AAC.

The current classes that satisfy the capstone design requirement are EE109 (Digital Design Lab), EE133 (Analog Communications Design Lab), EE134 (Introduction to Photonics), EE144/EE245 (Wireless Electromagnetic Design Lab), EE168 (Introduction to Digital Image Processing), CS194 (Senior Software Project), E206 (Control System Design Lab), EE256 (Numerical Electromagnetics), EE262 (Two-Dimensional Imaging), and EE265 (Digital Signal Processing Lab). There is now at least one capstone design class coupled to each of the specialty sequences, as shown in the table below.

<table>
<thead>
<tr>
<th>Specialty Sequence</th>
<th>Related Capstone Design Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields and Waves</td>
<td>Wireless E&amp;M Lab (144), Numerical E&amp;M (256)</td>
</tr>
<tr>
<td>Solid State and Photonic Devices</td>
<td>Introduction to Photonics (134)</td>
</tr>
<tr>
<td>Circuits and Devices</td>
<td>Analog Communications Design Lab (133)</td>
</tr>
<tr>
<td>Signal Processing/Communications</td>
<td>Comm. Lab (133), Image Proc. (168,262), DSP (265)</td>
</tr>
<tr>
<td>Control Systems</td>
<td>Control Lab (E206)</td>
</tr>
<tr>
<td>Computer Hardware</td>
<td>Digital Design Lab (109)</td>
</tr>
<tr>
<td>Computer Software</td>
<td>Software Project (CS194)</td>
</tr>
</tbody>
</table>

Table 2: Specialty Sequences and Capstone Design Courses

### 3. Other Curriculum Issues

#### 3.1 Course Scheduling
It is essential that the scheduling of courses be monitored to avoid conflicts as much as possible; courses that students would want to take the same quarter should not be offered at the same time. This is particularly important for core courses, since not being able to take a core course a given quarter could delay subsequent specialty courses by a year or more. Faculty currently indicate possible conflicts for a course they are teaching on the course information sheet. This is a highly imperfect system, as faculty might not be aware of potentially conflicting courses, or may omit to fill out this part of the course information sheet. EE staff use the information on the course information sheets to identify conflicts after faculty have scheduled their courses. Given the difficulties of rescheduling courses, it seems a more proactive approach to identify and avoid conflicts should be put in place. In particular, while faculty should make every effort to identify potential conflicting courses with the ones they are teaching, EE staff and the undergraduate TA should also participate in this process. There should be a more formal mechanism to avoid scheduling conflicting courses at the same time, so that before faculty schedule their classes, they can coordinate with faculty of conflicting classes to find nonoverlapping course times.

The committee also recommends that all core courses be offered twice per year. Currently EE101AB and EE108A are offered twice, so this recommendation is basically to add another offering of EE102AB and EE108B. This will reduce scheduling difficulties for core courses, increase flexibility, and make it easier for students to spend 1-2 quarters in the overseas program. The downside to this recommendation is staffing: faculty covering these additional offerings would not be available to teach other courses, and it is not clear there is sufficient interest among faculty teaching these courses to offer them twice per year. Core courses should not be given by irregulars or teaching fellows. Thus, we recommend that all core courses be offered twice per year if this does not impact the teaching of other key graduate and undergraduate courses, and if they can be staffed by regular faculty. Otherwise these courses should be offered once per year. In the course planning stages, the AAC will include two offerings of all core courses per year, and it will be up to the sponsoring labs to staff them or to reduce that number to one. This recommendation was put in place last year, but so far there has not been sufficient staffing or faculty interest to support two offerings of all core classes.

3.2 Stanford Overseas Studies Program

One of the goals of increasing flexibility in the new core was to facilitate students spending one or two quarters in Stanford’s Overseas Studies Program. Students enrolled in this program take classes in a Stanford center abroad while remaining enrolled at Stanford and receiving direct Stanford credit for their courses. Given the globalization in the field of engineering and related fields, it is becoming increasingly important for our majors to participate in overseas programs. However, these opportunities are limited for EE majors due to the large number of required classes in the major and the limited offering of EE and relevant engineering courses in the overseas centers. In particular, while Stanford operates centers in Australia, Beijing, Berlin, Florence, Kyoto, Moscow, Oxford, Paris, and Santiago, only Kyoto offers EE courses (specifically EE101B and EE108B), and only Kyoto, Berlin, and Paris offer ENGR40. Since most EE classes, including core classes, are only offered once a year, spending even just 1 quarter abroad can delay a core course sequence or courses in a specialty sequence by up to a year.

This problem is not unique to EE majors, and impacts many undergraduates in the SOE. The dean’s office is looking into methods to make overseas study easier for all engineering students, including making SCPD classes available to students in Stanford centers abroad. While many of our undergraduate classes are not offered through SCPD, this would at least provide some improvement in the courses that students could take while abroad. We recommend that the department provide feedback and input to the school to facilitate overseas study through SCPD and other new approaches. EE faculty should also be encouraged to consider participating in the overseas program, as this would increase the EE courses offered at Stanford centers abroad.
Although not formally part of the Overseas Studies Program, EE majors can receive credit for study abroad at École Centrale Paris. École Centrale Paris is one of the best known science and engineering schools in France and Europe. Stanford students are enrolled in engineering program classes with French and International Students, and credit for these classes is transferred to Stanford. Instruction is mostly in French, and students are expected to have 1 year of college level French prior to entering the program.

3.3 The CSE Major

One of the committee’s charges was to determine the enthusiasm, if any, for EE participation in the Computer and Systems Engineering (CSE) major, possibly as an Interdisciplinary Program (IDP). We discussed within the committee and with relevant faculty whether EE should participate in the CSE major as an IDP program between EE and CS. While there was no objection to the program in principle, it seems that with the new flexibility in the EE core, it's not clear that the benefits of such a program to EE undergraduates are worth the effort and manpower required to support it. There does not seem to be much enthusiasm within EE in participating, and no EE faculty is willing to play the role of champion for EE participation. CSE is currently an Individually Designed Major within the SOE. These majors are reviewed every 5 years by the campus-wide committee on undergraduate majors (CRUM). The next review of the program is 2006/2007. However, this type of review is much less stringent than the review of an IDP, and is unlikely to bring about major changes or an end to the major. Our recommendation was that the EE department not participate in the CSE major, although it will continue to be offered through the school as an Individually Designed Major.

4. Broader Issues: Improving the Undergraduate Experience

4.1 Research Opportunities: The REU program

The REU program is extremely successful and a great draw to the major. This program allows undergraduates to spend a summer in a research lab under the supervision of a faculty member, with on-campus housing in the Summer Research College and a stipend. The program is fully funded by the SOE, and a student must be a declared EE major to participate. This program provides a great educational experience for our undergraduates and should be supported and promoted as much as possible. The table below shows the number of students participating in the REU program each year since its inception. Note that this year shows the largest number of students, with approximately half of all EE majors participating in the program.

<table>
<thead>
<tr>
<th>Year</th>
<th>Students in REU Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>47</td>
</tr>
<tr>
<td>2001</td>
<td>38</td>
</tr>
<tr>
<td>2002</td>
<td>37</td>
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<td>2003</td>
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<tr>
<td>2004</td>
<td>35</td>
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<tr>
<td>2005</td>
<td>45</td>
</tr>
<tr>
<td>2006</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 1. REU student participation.

4.2 Faculty Interaction

Many of our undergraduates do not interact much with their faculty advisor, other than to get forms signed. While the undergraduate TA and student peers do a wonderful job advising students on courses
and planning, the students would benefit in planning their coursework and future career from the broader perspective that a faculty member could provide. The REU program has been an excellent mechanism for undergraduates to work closely with faculty and seek their advice during and after the program. Faculty that teach undergraduate courses also become de-facto advisors for enrolled students in some cases. The department could do more to promote interaction between faculty and undergraduates, including encouraging faculty to do more undergraduate EE and freshman advising, and perhaps hosting social events where students could meet faculty in an informal setting. We recommend that the AAC examine this issue in more depth and propose some recommendations.

### 4.3 Diversity

The percentage of women and minority undergraduates in EE at Stanford, and at universities nationwide, is small and stagnant. Increasing the diversity of our undergraduates is an important goal, as it will improve the pool of outstanding students that consider an EE major, provide a richer and more creative educational experience for all students, produce a generation of engineers with new perspectives based on their diverse backgrounds, and improve the pool of women and minorities that might consider graduate EE programs. Increasing the number of women and minorities that major in EE is a deep and complex problem with no simple solution. Thus, a big improvement in the diversity of our student population cannot realistically be expected in the short term. However, since the current percentages are so small, even a small increase in the number of such students will make a big difference to the current student population. Moreover, as more women and minorities enter the major, they create role models and recruiters for others, so a small improvement now can lead to bigger improvements down the road.

The issue of diversity among EE majors is beyond the scope of our committee and the AAC. We suggest that the department appoint a committee to study this issue and propose recommendations to address it. Some recommendations to consider include the following:

1. Increased participation by EE faculty in freshman advising of minority students interested in engineering.
2. Increased participation by EE faculty in Stanford’s Summer Engineering Academy (SSEA, [http://soe.stanford.edu/edp/programs/ssea.html](http://soe.stanford.edu/edp/programs/ssea.html)). This program invites women and minority admitted freshmen that are interested in engineering to live on campus one month before the start of their freshman year. During that month, they take mini-classes from faculty on math, physics, and engineering to help prepare them for their major. The format of the classes is up to the faculty, some teach weekly lectures over the entire program, and others present a single one-hour module. The students also develop a peer group and faculty mentors at the very beginning of their Stanford experience. This program has been very successful in increasing the diversity of students in engineering and making the major more inviting and rewarding.
3. Departmental partial or full scholarships for women and minority EE majors.

### 5 Challenges to Maintaining a Strong EE Major

There are many challenges to maintaining an outstanding EE undergraduate program at Stanford. At most top EE departments, such as Berkeley and MIT, students apply and are admitted directly to the department as freshman. At Stanford the university admits students campus-wide and then students are free to choose any major, and need not do so until the end of their sophomore year. Thus our department competes with all other departments on campus for the best students. Stanford also imposes a rich set of liberal arts requirements on all undergraduates, which limits the number of courses that can be required in the EE
major (in fact, EE has the largest number of required units of any department). Our undergraduate program is quite small, graduating about 40 students per year, and is not likely to grow significantly given Stanford’s admission process. The undergraduate program also competes for resources and faculty attention with our large Masters and Ph.D. programs. Finally, the nature of EE is changing: it is becoming more interdisciplinary while at the same time many jobs associated with the core EE discipline are moving overseas. The challenge to our department is to maintain the excellence and relevance of our EE undergraduate major in the face of these ongoing challenges. We believe that these challenges are best met by making our EE major dynamic, relevant, exciting, and fun: a program of this nature will attract the best students along with faculty interest and innovation. Maintaining excellence in our undergraduate major, addressing the ongoing challenges, and adapting to the changing nature of the EE field and profession will require continued oversight and evaluation of the existing program, as well as a periodic thorough evaluation of the EE major to identify problems and initiate new ideas and experiments to address them.

6 Recommendations for Ongoing Oversight

The undergraduate curriculum committee was responsible for a comprehensive evaluation of the EE undergraduate curriculum, and then recommending and implementing changes to the curriculum to make it more rewarding, relevant, and fun. The committee’s work is now complete, and we therefore recommend that our committee be disbanded. However, continued monitoring and oversight is critical to maintain the excellence of the EE major over time. The AAC maintains responsibility for the undergraduate and graduate programs, but there is no one within the AAC whose sole focus is on undergraduate issues. Given the large number of undergraduate issues that require ongoing monitoring as outlined below, as well as new issues impacting the undergraduate major that will arise, we believe that one person on the AAC other than the vice chair should be made responsible for undergraduate issues. We therefore recommend that a new position be created within the AAC, perhaps a vice chair for undergraduate affairs, with the responsibility of ongoing monitoring and resolution of issues related to the undergraduate curriculum and experience. In particular, this person would monitor and address the following issues on an ongoing basis, as well as any new issues that arise:

1. **Evaluation of core courses and their lab components**: Since these courses are the first introduction our students get to the major, it is important to make sure they continue to be motivating, valuable, and a core introduction to EE. It is especially critical that the lab components of these courses be monitored, as students have complained that the workload for the lab in some core courses is excessive and detracts from their other classes. Since the lab components of core courses is a new requirement, we recommend that the lab component of the core courses be thoroughly evaluated within the next two years to ensure a balanced workload and valuable experience for the students. This evaluation should include an assessment of the impact of the fact that E40 is no longer required.

2. **Freshman seminars**: The department should offer 3-5 freshman seminars each year. This requires proactive solicitation of faculty to offer such courses. Moreover, freshman seminars are offered through the office of freshman/sophomore programs and are not controlled by the department or AAC. Thus, freshman seminars require the department chair to submit a list of approved seminars to the freshman/sophomore program office each year.

3. **Updates to and expansion of specialty sequences**: 100 and 200 level courses are constantly changing, and the specialty sequences should reflect such changes, and also be updated to remove, add, or merge sequences as course offerings change. Faculty should also be encouraged to develop new 100 and 200 level classes that are accessible to EE undergraduates.
4. **Expansion of capstone design courses:** New courses should be monitored to see if they fall under the capstone design guidelines. If so they should be added to the list of classes that satisfy this requirement. Faculty should also be encouraged to develop such courses.

5. **Expansion of introductory design courses:** We currently have one EE course, EE122 (analog design laboratory), that falls in the category of introductory design. Students can take this class right after ENGR40 for early exposure to open-ended design problems. Many students find engineering design to be one of the most fun, useful, and satisfying aspects of the undergraduate major. Thus, our undergraduates would greatly benefit from more introductory design classes in areas other than analog design, in particular in the core EE areas of signal processing/linear systems and digital systems. Faculty should be encouraged to develop additional introductory design classes. Moreover, if introductory design courses were to be offered in all core areas, then we recommend that the AAC consider requiring EE majors to take one introductory design class in addition to the capstone design requirement.

6. **Course scheduling and conflict avoidance:** The AAC should put in place a more formal mechanism for scheduling both core and upper division EE courses to avoid conflicts as much as possible. Most undergraduate courses are offered the same quarter every year, so most of the conflicts can be avoided by identifying in advance which courses should not conflict, and then coordinating between the faculty of those courses to offer them at nonoverlapping times. We recommend that the AAC generate the list of courses that should not conflict before faculty schedule their classes for the coming academic year, coordinate with faculty via the lab representatives so that conflicts are avoided in scheduling classes, and monitoring class schedules when they are first entered into the bulletin to catch any remaining conflicts. The committee also recommends that the department try to offer all core courses twice per year to reduce conflicts and increase flexibility. The AAC holds responsibility for pushing to make this happen.

7. **Undergraduate Handbook:** The EE portion of the SOE undergraduate handbook is the most important resource about our curriculum for undergraduates that have declared or are considering the EE major. The AAC and undergraduate TA should ensure that handbook information is accurate and up-to-date. The current flowchart is out-of-date, does not capture many components of the undergraduate curriculum (e.g. freshman seminars and the capstone design project), and does not indicate flexible options such as replacing Math 51/52/53 with CME 100/102/104. Perhaps a flowchart similar to Figure 1 could replace the existing flowchart in the handbook. It would also be useful to add a program sheet in the handbook for students that participate in the overseas program.

8. **Facilitating 1-2 quarters abroad:** We recommend that the department consider ways to increase participation of EE majors in the Stanford Overseas and Ecole Centrale Paris Programs. This includes making students more aware of these programs and their value through faculty advisors and the undergraduate TA. Program planning sheets should be available that show students how a quarter or two abroad can be incorporated into their programs. The department should also participate in the SOE activities to facilitate overseas study through SCPD and other new approaches, and EE faculty should also be encouraged to consider participating in the overseas program.

9. **Soliciting student feedback:** An automated mechanism should be put in place to solicit feedback from all EE majors each year, and also to solicit feedback from these students after they graduate. The ABET survey in the upcoming 2006/2007 academic year requires such feedback, and so whatever method is used to obtain it should be used on an annual basis.
10. *Increase Interaction with Faculty and Student Diversity*: The department can put additional emphasis on increasing interaction between EE majors and the faculty outside the classroom, and also on increasing the diversity of the students majoring in EE.

11. *Periodic Curriculum Evaluation*: While ongoing monitoring is valuable, it is no substitute for a thorough evaluation of all components of the curriculum on a regular basis. We recommend that a committee be formed approximately every five years to examine the undergraduate curriculum in its entirety, recommend changes, and see that these changes are implemented.
Appendix A: Summary of Student Feedback

The chair and vice chair had a series of lunches with graduating seniors in the spring quarter of 2004 to get their feedback on the EE curriculum. Most of the discussion was devoted to the new core and the relative merits of the new core with respect to the old. These students had seen the transition phase. Note that the comments below were the result of a discussion with a very limited number of graduating seniors the year after the transition to the new core, and these are students who appear to have been very successful here. The ABET survey is a broader method of getting student feedback, but the last survey in 2002 preceeded the rollout of the new core. A new survey will be held with the upcoming ABET evaluation in the 2006/2007 academic year, which should provide useful information from students about the new core.

The primary goals of the new core were to reduce the number of required core course a student had to take before moving on to more advanced courses and to allow more flexibility in program planning. For two of the core areas the change resulted in the compression of three courses of three units each into two four-unit courses with lab sections. For one of the areas the requirements increased from a single course to two four-unit courses.

In general these students felt that the new sequences introduced too much material for the time allowed and in one case did not provide sufficient preparation for follow-up courses. Most notably, there was a strong feeling that in comparison with the old electronics sequence, the new 101AB sequence was inadequate in terms of preparation for subsequent courses. It was pointed out that the 8-unit 101AB is a compressed version of portions of 101, 111, 112, 113: 12 units being reduced to 8. Several students felt that as a result the new sequence has too much material for the time allotted and yet it still missed some important and necessary topics. There was a feeling that some “tweaking,” rather than major restructuring, can fix most of the problems, but some students felt that a three quarter sequences would do a better job of preparing students for subsequent. The opinion was voiced that the old core did a better job of separating distinguishable topics into individual courses and dealing with each in sufficient detail to provide a solid foundation. In contrast the new core had overlapping topics and more superficial treatments that did not leave students as well prepared.

Another specific criticism which was strongly made by several (but not all) of the students was that 10A (and perhaps 108B to some extent) was more work than the intellectual content justified -- too much time was spent on quizzes, exams, and debugging Verilog. The workload was notably higher than the other core courses without compensating benefits.

Several specific suggestions were made toward improving the situation:

- The EE 102AB sequence is very similar to the old 102,103 courses. These course do not need a lab or to have 4 units. The Matlab "labs" should be incorporated into the ordinary homework. Note that this has already been done in the current version of these classes.

- EE101AB needs to provide more device material and to have an additional required class devoted to serious lab work. Perhaps reduce these courses to 3 units, with a concentrated lab course following these courses. Several students felt that the old EE 113 final project was a valuable learning experience that is lost in the new 101AB core.

- In EE108A, the content is fine and the final project should be kept, but the workload needs to be reduced. Combine the problem sets and prelabs, and reduce the number of exams and quizzes.

Other suggestions and comments on various issues raised during the discussion were the following.
- CS 106 should no longer be required as an engineering fundamental since more students have had the equivalent course in basic programming before coming to Stanford. A better, more flexible, requirement would be to require either CS 106 or CS 107. CS 107 should not, however, be allowed to count both as an engineering fundamental and as part of a specialty sequence.

- Leave ENGR40 alone. It was the reason one of these students declared EE. It was generally agreed that not requiring ENGR40 was reasonable since those students who need it will still take it. Freshman seminars should serve as the attractors to EE.

- Do not have “overview” classes

- Most undergraduates do not take advantage of the many 200 level courses. EE 261 is an exception. It was felt that some 200 level courses might be structured so as to have a corresponding 100 level course, possibly using the same basic material but having differing requirements/homework/exams and grading for undergraduates and graduates. EE 215 was cited as an example where an EE 115 could provide background in BJTs for undergraduates without them having to compete directly with graduate students. The dual class 144/245 was mentioned as an example.

- A desire was expressed for a good mechatronics class for EEs. The former course, EE118, was dropped because of staffing problems, but no course has been proposed to replace it.

- Student like the idea of multiple concentrated doses of a subject that is possible with the quarter system.

- The reduction in the core requirements leaves students less well prepared for multidisciplinary work.

- It was observed that opportunities for interdisciplinary projects are rare within EE, yet much work in the real world involve EEs working with a wide range of other professionals. This can cause culture shock when students are not adequately prepared for multidisciplinary teamwork.
Appendix B: Capstone Design Course Guidelines

While ABET guidelines for the EE undergraduate curriculum requires a capstone design course, ABET provides no formal definition of what is required in such a course. The undergraduate committee has recommended that courses approved by the AAC to satisfy the capstone design requirement in the EE curriculum satisfy the following guidelines.

Guidelines for Capstone Design Courses

Course Objective
“Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating engineering standards and realistic constraints.”

Course Requirements

1. Level: Must be at the “senior” level.

   *Rationale:* This is required to be a *culminating* design experience.

2. Prerequisites: Must include as prerequisites all relevant core-curriculum courses and at least one 100-level (or above) course.

   *Rationale:* The course is required to be a culminating experience *based on the knowledge and skills acquired in earlier coursework.*

3. Design component: Design must be the major component of the course. Students should explore and evaluate possible design alternatives. Students working in a team on the design should have each member of the team playing an active role in the design activities.

   *Rationale:* The course is required to be a *major design experience.*

4. Course content: The course must incorporate consideration of as many of the following issues as are appropriate to the course:

   a) Realistic constraints: This may, for example, involve space, time, complexity, etc. considerations in the implementation. These issues may be addressed in the lectures, and students should be consciously aware of these considerations, perhaps via class discussions, even if they don't play an explicit role in the actual design project.

   b) Design tools: In at least some of the capstone courses, it should be possible to discuss and use (industry) standard design tools (e.g., HSPICE, VERILOG, CADENCE, MATLAB).

   c) Standards: In the case of at least some of the capstone courses, it should be possible to discuss standards (e.g., IEEE, FCC). Even if the design project doesn't involve standards in a direct manner, students should be aware of these considerations.
d) Maintainability: The design should include consideration of how to make the system maintainable to perhaps accommodate changing requirements or to continue functioning in a somewhat different environment etc.

e). Ethical, social issues, environmental: Issues relating to such matters as security, privacy, etc., are often directly related to the general area of the capstone courses even if not necessarily with the particular projects. Hence, students should again be consciously aware of these issues, perhaps via class discussions.

*Rationale:* The capstone course is where the students are supposed to be trained to work on projects of the kind they are most likely to work on in at least the early part of their professional careers. Therefore it is reasonable to make these projects as realistic as possible.

5. Documentation: Deliverables should include suitable documentation of both the design and any significant implementation performed in the project. The grading scheme should account for the quality of the documentation.

*Rationale:* Oral and written communications are important and the capstone course is an appropriate venue in which to practice these skills.

6. Oral presentation: Each student should be required to make at least one significant oral presentation (10 minutes or longer), or two or more shorter presentations about his/her design/implementation. The grading scheme should account for the quality of the presentation(s), possibly using peer evaluation for the purpose.

*Rationale:* See above.

7. Team working: It is strongly encouraged that students be organized into appropriate teams for working on their design projects.

*Rationale:* Team working is another important skill. Both the nature of the capstone courses and the fact that these courses have their enrollment capped make them good candidates for team working.

8. Course size: Enrollment in each section of capstone courses should be capped.

*Rationale:* To enable team working as well as oral presentations.