1. Executive Summary

The Department of Electrical and Computer Engineering (ECE) at Boston University is a medium-size Research-I department with a current enrollment of 276 BS, 78 MS, and 108 PhD students. It offers BS, MS and PhD degree programs in Electrical Engineering (EE) and Computer Systems Engineering (CSE) and a new MS degree in Photonics. Both undergraduate programs are accredited by ABET. The Department has 43.5 FTE faculty, bringing in approximately $9M in new grants and contracts in FY2004-05. Departmental facilities occupy about 55,000 ft² in the Photonics Building.

ECE is a multidisciplinary department with a strong systems perspective. The faculty have been trained in electrical engineering, computer engineering, physics, mathematics, chemistry, computer science, and information systems. There are three overlapping areas of research and instruction; Electrophysics, which includes photonics, solid state materials and devices, and electromagnetics & space physics; Information Systems & Sciences, which includes signal and image processing, control and communication systems, and networks; and Computer Systems Engineering, which includes hardware, software applications, and computer networks. The faculty have collegial ties to important BU research centers and pursue collaborative cross-disciplinary research with faculty in many other BU departments.

Our long-term goals and strategies are: 1) To propel the ECE Department into the top 30 in the US, and the top 5 among private, liberal-arts universities with an engineering program, by enhancing the true quality of our programs and our faculty and student body, and by enhancing our national visibility through a concerted publicity effort. We also aim at becoming number 1 in a few sub-areas of research. 2) To continue to focus on a few important interdisciplinary areas of excellence that will create outstanding programs of research and innovation while contributing to a strong undergraduate learning experience and cutting edge graduate research. This will require faculty stability and growth and continued University support for curriculum and laboratory development. 3) To be aggressive and opportunistic in pursuit of emerging areas of ECE through realignment of our programs and by selection of new and replacement faculty. 4) To nurture alumni for increased participation in departmental activities and donation of funds for scholarships and endowed professorships.

In pursuit of educational excellence, we wish to design an ECE undergraduate program that strikes a balance between engineering theory and practice, between technical/scientific education and general/liberal-arts education, and between preparation for “rank and file” roles and preparation for “leadership” roles. Our vision is to provide our students with an integrated view of the broad and rapidly changing ECE discipline. We wish to elevate the graduate program to a nationally competitive level capable of attracting top students, and develop relevant and exciting programs that build upon interdisciplinary strength in crosscutting areas. Our strategy for achieving research and scholarly excellence is to pursue a number of collaborative research initiatives in important research areas, such as semiconductor optoelectronics, biosensing and imaging, quantum information technology, distributed information processing, networked embedded computer systems; and to strive for a significant increase in research funding. Racial and gender diversity in the Department needs to be improved at all levels.

Our three short-term priorities are: 1) To increase the appeal of our undergraduate program by improving the attractiveness, relevance, and flexibility of the curriculum. 2) To enhance our visibility as a leading department by pursuing large collaborative research, educational, training, and international-partnership grants, and by seeking leadership positions for our faculty in professional societies. 3) To realign and strengthen our partnership with the Photonics Center.

This plan was developed by the Planning Committee of the ECE Department, and vetted by the ECE faculty during the months of January and February of 2006. Earlier drafts of this document were posted on the Web for faculty comments and the plan was discussed extensively at two faculty meetings.
2. Background

2.1 Mission

The **mission** of the Department of Electrical and Computer Engineering (ECE) Department is:
- To *educate* our students to meet high standards of excellence in electrical and computer engineering in preparation for professional careers and advanced studies.
- To *create and disseminate new knowledge* through basic and applied research in electrical and computer engineering.
- To *serve as a resource* of electrical and computer engineering expertise at the local, regional, and national levels.

2.2 Faculty, Staff, and Resources

2.2.1 Brief History of the ECE Department

Founded in 1970 as the *Department of Systems Engineering*, the Department rapidly embraced the emerging field of computer engineering and became the *Department of Systems and Computer Engineering (SC)* in 1976. As its scope broadened further over the years, it became the *Department of Electrical, Computers, and Systems Engineering (ECS)* in 1981. Interest in the undergraduate *Systems* program subsequently declined, and the name of the Department was changed again in 1996 to the current name, ECE (A PhD degree in *Systems* is currently offered at the College level).

The Department grew substantially in the mid 1980s under the leadership of Dean Louis Padulo, and as undergraduate enrollment soared, the size of the faculty doubled, from 16 to 32, in 5 years. This period also witnessed the creation of a popular Corporate Classroom program, which reached a peak enrollment of more than 700 and lasted for a decade.

During the administration of Dean Charles DeLisi in the 1990s, a strong research focus emerged, and a new Department Chair, Bahaa Saleh, was appointed in 1994. Saleh has continued the effort to expand research in targeted areas, and the Department gradually matured from a primarily undergraduate teaching program in previous decades to a Research-I department with high quality undergraduate and graduate instruction, a substantial research program, and an increasingly distinguished faculty. The number of faculty increased to the current number of 43.5 FTE and external research grants and contracts increased from $2.0-2.5M in the early 1990s to $9M in FY2004-05. The relocation of the Department to the new Photonics Building in the Spring of 1997 has provided faculty and students with excellent research and instructional facilities. The Department now attracts outstanding students and faculty, leads and participates in major research centers, and is gradually gaining an excellent reputation in the professional community.

2.2.2 Faculty and Staff

The instructional and research mission of the Department is met by a total of 43.5 FTE faculty members (38.5 tenured or tenure-track and five non-tenure-track of which two are research faculty). Additionally, 10 faculty members in other departments have affiliate appointments in the ECE Department; they often serve as ECE graduate student advisors and research collaborators. ECE is a **multidisciplinary department** with a strong systems perspective. The faculty have been trained in electrical engineering, computer engineering, physics, mathematics, chemistry, computer science, and information systems.

ECE faculty have been recognized by awards and honors, including the prestigious **NSF CAREER Award**, which was received by 11 ECE faculty in their junior years. Additionally, 3 ECE faculty received the **ONR Young Investigator Award**, and one was honored by a **PECASE Award**. Honored senior faculty include 6 **IEEE Fellows**, 4 **OSA Fellows**, 3 **APS Fellows**, 2 Fellows of the Amer. Inst. for Medical & Biological Eng. (AIMBE), and one Fellow of each of the Electrostatics Society of America, the Electrochemical Society, and the American Society for Lasers in Medicine and Surgery. Several faculty are authors of well known textbooks and monographs, and several have served as editors or associate editors of a number of key journals, including: *IEEE Transactions on Automatic Control, IEEE Trans. Image Processing, IEEE Journal of Quantum Electronics, Signal Processing Letters, Computational Optimization and Applications, Journal of Electrostatics, Solid State Electronics, Journal of Geophysical Research,*...
The instructional mission of the Department includes offering BS, MS and PhD degree programs in Electrical Engineering (EE) and Computer Systems Engineering (CSE) and a new MS degree in Photonics. Both undergraduate programs are accredited by ABET.

There are three overlapping academic areas of research and instruction in the Department:

i) **Electrophysics (EP)**, which includes photonics, solid state materials and devices, and electromagnetics and space physics

ii) **Information Systems & Sciences (ISS)**, which includes signal and image processing, control and communication systems and networks

iii) **Computer Systems Engineering (CSE)**, which includes hardware, software applications, and computer networks.

The expertise of the ECE faculty are mapped to the instructional and research needs in the various specializations, as shown in the following table:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>FTE Faculty</th>
<th>Research</th>
<th>FTE Faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE Program</td>
<td>29.5</td>
<td>EP</td>
<td>17.5</td>
</tr>
<tr>
<td>CSE Program</td>
<td>14</td>
<td>ISS</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CSE</td>
<td>14</td>
</tr>
</tbody>
</table>

As shown in the following table, the distribution of faculty among the ranks is healthy, and many outstanding junior faculty are in a position to provide leadership for the Department in years to come:

<table>
<thead>
<tr>
<th></th>
<th>Assistant Professors</th>
<th>Associate Professors</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenure/Tenure-Track</td>
<td>10</td>
<td>10</td>
<td>18.5</td>
</tr>
<tr>
<td>Non-Tenure-Track</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Administrative and Technical Staff development has lagged behind growth in the faculty and graduate student body and research volume, including the number of postdoctoral fellows and visiting scholars. The administrative staff of 7 remains inadequate for the current administrative demands. The technical staff of 3 systems experts and 3 laboratory assistants is meeting our needs, but further expansion would require the addition of specialized staff.

### 2.2.3 Composition of Faculty: History

In the last decade, the Department has been able to achieve net growth despite a large number of faculty departures caused by retirement, termination of appointment of inactive faculty, and other institutions attracting some of our successful faculty (See Chart in Appendix 5.1). The absence of turnover in the last two years has helped, and the morale of the faculty is currently high. Some retirements are expected in the near future and one has already been announced. Proactive action to prevent attrition is necessary and action to fill open positions will maintain the stability of the Department. Additionally, new faculty are needed in certain strategic areas, particularly areas synergistic with other departments and centers.

During the era of high CSE enrollment in the late 1990, the Department sought to add new faculty in the computer area, but this effort was not fully successful because of competitive forces. With the CSE enrollment decline, the faculty composition is more balanced, although some needs of the CSE graduate program remain incompletely met.

As a result of a strong emphasis on research, research funding has grown significantly in the last decade. Total annual new research funding in the last five years averaged to approximately $7.1M, compared to $5.2M in the 1996-00 period, and $2.4M in1990-95. The number of non-research-active faculty is diminishing but is still greater than we would like.

### 2.2.4 Peers/Competitors

The following peers/competitors have been selected from among private Research-Doctoral Carnegie Class universities with EE and CSE programs. Duke University has been in the list of our Educational Benchmarking Incorporated (EBI) peers for a number of years. Graduating seniors are surveyed each year by EBI for ABET planning.
2.2.5 Financial Resources

Over the past decade the funding resources for the ECE Department have been predominately a University funded Base Budget, which has been augmented by faculty buyouts from grant awards, Indirect Cost Recovery from grant expenditures, and special additions to the base budget to fund a continuing ABET requirement to update equipment and materials utilized in the ECE Instructional Laboratories. In addition, the department has received support from the University as cost sharing for the ERC-CenSSIS program. In the past the Department was permitted to use open faculty lines to meet its budget targets, but the College has held that source of funding centrally in later years. Also, in the previous decade the Department received funds from two external funding sources (SECAP - Software Engineering Corporate Advisory Program and the Corporate Classrooms Program). Both of these programs have terminated due to lack of corporate participation following the economic downturn. No funding has been received from the University endowment.

Faculty research is of course funded by external grants. Research funding has grown significantly in the last decade, as depicted in the chart in Appendix 5.2 (The composition of this funding among different sources is discussed in Sec. 2.4.3.). Despite the increase in external research funding, faculty buyout has dropped in recent years and is currently $120k. The predominant funding agency, NSF, does not permit faculty buyouts.

2.3 Educational Programs

2.3.1 Undergraduate & Graduate Programs

The ECE Department offers BS, MS and PhD degree programs in Electrical Engineering (EE) and Computer Systems Engineering (CSE) and a new MS degree in Photonics. Both undergraduate programs were re-accredited by ABET in 2004. In AY05-06, the Department enrolled 276 undergraduates, 78 MS students, and 108 PhD students.

As the the history charts in Appendices 3.3-3.5 show, the enrollment and degrees awarded in the various ECE programs have had dramatic changes over the years as the Department evolved from a predominantly undergraduate student population in the mid 1990s, with a nearly 3 to 1 undergraduate to graduate enrollment, to the more balanced distribution of a 3 to 2 ratio today.

Undergraduate Programs

The history of undergraduate enrollment in EE and CSE has mirrored national patterns. While the enrollment in the EE program remained stable in the last decade, and has shown some increase in the last few years, CSE enrollment has declined sharply after an 8-year “bubble” between 1995 and 2002. Enrollment in CSE is now significantly below that of EE. Nevertheless, based on occupational employment projections, the CSE enrollment is expected to bounce back in years to come.1

In accordance with the College mission the EE/CSE programs provide the students with “rigorous education to prepare students to become highly qualified engineers and the technology leaders of tomorrow.” The students are exposed to a rigorous, thorough and hands-on professional component that encompasses electrical and computer engineering and a good deal of other engineering disciplines. As the ABET visiting team observed in 2004, the program “provides an exceptional laboratory experience. The facilities and equipment are excellent. The lab experience is well integrated into the curriculum, well planned, and well taught. The faculty is highly qualified and enthusiastic about the positive direction of the

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1 A recent study by D. Hecker, “Occupational employment projections to 2014,” published in the November, 2005, issue of the Monthly Labor Review, projects that computer specialists will be among the fastest growing occupations in the 2004-14 decade, with an increase of approximately 30% (40% for computer software engineers, and 11% for EEs).
program in recent years, and is eager to participate in achieving the high quality objectives the program has established. The student body is well qualified and feels well served by the program,” and “the capstone project provides an entrepreneurial experience for the students and exposes them to the real world problems of schedule and knowledge gaps.”

The Department has a strong commitment to the philosophy and process of quality improvement in academic programs. We rely on student surveys, student feedback forums, faculty review of courses and outcomes, and proposal and implementation of curriculum changes aimed at improving program outcomes. Our Industrial Advisory Board plays a strong role in providing input to the program and closing the loop of our continuous improvement process. We continue to improve the curriculum, maintain the laboratory facilities and invest in updating its equipment. The only unmet ABET concern has been the inadequacy of the engineering library.

Undergraduates are encouraged to get involved with research and development efforts in faculty labs through NSF REU, UROP (Undergraduate Research Opportunity Program), work study, or student employment. Engineering is an applied science, and we believe it is important to start applying what is learned in the classroom as soon as possible.

Graduate Programs

The ECE graduate programs have changed dramatically in the last couple of decades, with the emphasis shifting from a professional MS-oriented program and a strong Corporate Classroom enterprise to a strong PhD program (see Appendices 5.3 and 5.5 for historic data). In the early 1990s, we granted more than 100 MS degrees per year. With priority shifting to the PhD programs, MS degrees declined to less than 30 per year by the late 1990s. Realizing the need to reverse this decline, we began initiatives to strengthen the MS student population in order to enhance the overall vitality of the graduate programs. The MS enrollment bounced back and has steadily grown in the 2000s. The number of MS degrees awarded annually has now increased to more than 70.

Our strong emphasis on research has resulted in a steady increase in enrollment in the doctoral program, doubling in ten years, reaching an all-time high of 108. The number of PhD degrees awarded per year slowly increased from an annual average of 5 in the early 1990s to 10 the last few years.

Graduate teaching fellowship resources have declined slightly, while RA support has grown with grant funding. ECE PhD students have earned numerous Dean’s Fellowships and prestigious external fellowship from NSF, DARPA, and the Gates Foundation. Nearly all current PhD students are funded. It is fair to say that the Department has now created a vigorous graduate program.

Our peer institutions and competitors for recruiting graduate students vary with specific areas. In the Boston area we compete with peers such as Brown University and MIT for the top students. Away from Boston, University of Rochester, Carnegie Mellon University, Stanford, University of Washington, UCSB, UCSD, Johns Hopkins, and Georgia Tech are among the schools to whom we have lost potential students.

2.3.2 Outcome for Students in ECE Programs

Undergraduate Program

The objectives of the ECE undergraduate programs are:

<table>
<thead>
<tr>
<th>Two to five years after graduation, students are expected to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Build a career path with informed choices about its EE/CSE aspects.</td>
</tr>
<tr>
<td>● Be competitive in the EE/CSE job market.</td>
</tr>
<tr>
<td>● Contribute to the well-being of profession/community.</td>
</tr>
</tbody>
</table>

AND pursue one or more of the following:

| ● Graduate education in engineering or allied fields. |
| ● Breadth of responsibilities in a small company environment. |
| ● Specialized expertise within a large company environment. |
| ● Sales/Marketing positions in technology companies. |
| ● Basic and applied research. |
| ● Applications in other professions, such as medicine, and law. |

The following expectations for the career paths of our graduates have been expressed:

- A minimum of 20% and a maximum of 75% pursue careers requiring specialized expertise within a large company environment.
- A minimum of 10% and a maximum of 60% pursue careers with breadth of responsibilities in a small
A maximum of 25% pursue careers in **sales/marketing** in technology companies.
- A minimum of 10% of our graduates pursue **basic and applied research** within their first 5 years.
- A maximum of 20% of our graduates pursue careers in **engineering applications in other professions**, such as medicine and law.

The following are actual data provided by the BU/ENG Career Services Office, based upon a survey of about 250 ECE graduates at the time of graduation in the period 2001-05:

<table>
<thead>
<tr>
<th>Graduate School</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large ECE Employers (e.g., Raytheon, Teradyne, IBM, BAE, Microsoft, Lockheed Martin, Motorola)</td>
<td>45%</td>
</tr>
<tr>
<td>Medium/Small ECE Employers (e.g., Con Edison, NStar, Disney, Citibank, Net2Phone)</td>
<td>30%</td>
</tr>
<tr>
<td>Non-ECE Employment (e.g., Financial Analysts, Patent Examiners, Teachers)</td>
<td>10%</td>
</tr>
<tr>
<td>Military</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Graduate Programs**

PhD students tend to go into post-doctoral positions, government labs, and industry, and a few go into academia. MS students tend to go into industry (technical & sales), while a few go on to get PhDs, here and elsewhere. Actual statistics are being collected.

### 2.4 Research Programs

**Areas of Research**

The ECE Department has three overlapping areas of research; **Electrophysics**, which includes photonics, solid state materials and devices, and electromagnetics and space physics; **Information Systems & Sciences**, which includes signal and image processing, control and communication systems and networks; and **Computer Systems Engineering**, which includes hardware, software applications, and computer networks. These areas overlap as indicated in the schematic illustration in Figure 1. The following is a brief description of each of the research areas.

![Figure 1. ECE areas of research](image)

**A. Electrophysics**

Electrophysics encompasses several strong and emerging areas of electrical engineering, including photonics, solid-state materials and devices, nanotechnology, and space physics. The electrophysics faculty have strong campus collaborations with the Photonics Center, the Center for Nanoscience and Nanobiotechnology (CNN) and the Center for Space Physics and play key roles in the NSF Engineering Research Center (ERC) for Subsurface Sensing and Imaging Systems (CenSSIS).
**Photronics.** When BU established the Photonics Center, it made a strategic commitment to become a national center of excellence in photonics. World-class research facilities were developed and a number of senior and junior ECE faculty were added in the photonics area. The photonics faculty have infused many new courses into the curriculum, strengthening the PhD program and eventually leading to the creation of the new MS in Photonics degree program. The instructional program in photonics has been supported by external fellowships from the Department of Education and from curriculum development funds from industry and the National Science Foundation.

Research in photonics includes: photonic materials and devices (led by Ted Moustakas, a world renowned leader in nitride technology, Roberto Paiella, an expert in quantum-cascade lasers, and new faculty member Luca Dal Negro, who is developing a new facility in photonic-crystal devices); optical fibers (with a unique fabrication facility led by Ted Morse); quantum optics and its applications to imaging and secure communication (with a group of distinguished senior faculty, Bahaa Saleh, Alexander Sergienko, and Malvin Teich); optical imaging and microscopy (Selim Ünlü, who leads research in nanobioimaging associated with the Center for Nanoscience & Nanobiotechnology) and carbon nanotubes (Anna Swan). Biophotonics research is pursued by Irving Bigio, Anna Swan, and Selim Ünlü), and research in magneto-optics and optical storage is led by Michael Ruane and Floyd Humphrey. Research funding in this area has grown substantially in recent years, with a small fraction of the funds received through the Photonics Center. The 2000 award of Boston University’s first NSF ERC, the Center for Subsurface Sensing and Imaging Systems (CenSISS), was a significant and widely publicized accomplishment that has strengthened the sensing and imaging component of photonics.

The future of the BU photonics program depends on our ability to maintain the present large momentum by continuing to strengthen this program with new outstanding faculty in relevant areas. We have an opportunity to benefit from the outstanding facilities offered by the Photonics Center to launch large research initiatives in photonics.

**Semiconductor Materials & Devices.** This area overlaps naturally with photonics and we have deliberately emphasized this connection in an effort to strengthen the photonics program while meeting our instructional needs in the semiconductor area. The most senior faculty member in this area, Ted Moustakas, continues to lead a large research program in the more advanced family of Nitride Semiconductors, an area for which the group is recognized as one of the leading organizations in the world. The research is a combination of theoretical/modeling work in parallel with experimental studies of these advanced materials and corresponding devices. Intellectual Property derived from this work has been licensed by the University to major US and Japanese companies producing blue LEDs and blue lasers. Junior faculty member Roberto Paiella is involved applications of the nitrides to long-wavelength devices, including quantum cascade lasers, and Enrico Bellotti pursues world class, and well funded, research in numerical modeling of semiconductor materials and devices. The group is funded by DOE (for applications in solid state lighting), by DARPA and NASA (for the development of UV lasers and LEDs for identification of biological and chemical agents, by the Air Force (development of transistors for high power and high frequency applications) and by ARL (development of quantum cascade lasers). Fundamental work is supported by NSF, ONR and AFOSR-MURI. The group collaborates closely with members of the Physics Department. The most recent addition to this group is Luca Dal Negro, who is developing a laboratory in silicon light sources.

It is of great concern that the ECE Department has lost its silicon microelectromechanical (MEMS) fabrication facility and has not yet replaced it. Further, the space that was previously allocated for this purpose in the original plans of the Photonics building has been acquired by the Photonics Center for its commercialization activities. Establishing a modest-size silicon fabrication facility and recruiting in the area of micro- and/or nanotechnology has been, and must remain, one of our high priorities. The lab is necessary for our EE instructional program and for research in MEMS, optical MEMS, and nanotechnology.

Identified at the national level as critical to economic and security needs, nanotechnology encompasses research in areas related to photonics, biophotonics, and sensing and imaging systems, areas of longstanding interest in the Department. This is also consistent with university-wide initiatives and with our objective of maintaining a strong interest in photonic solid-state materials and devices. Growth plans and recruiting in this area must therefore be well coordinated at the University level.

**Electromagnetics & Space Physics.** Both the EP and the ISS groups have maintained collaborations with the Center for Space Physics (CSP). Two ECE faculty members (Bill Oliver and Josh Semeter) are directly involved in atmospheric and remote sensing studies, and others are involved in signal processing applications (David Castañon, Clem Karl, and Janusz Konrad) and instrumentation (Allyn Hubbard and Mike Ruane). Affiliate appointments for CSP/AST Professors Ted Fritz, Michael Mendillo, and Supriya
Chakrabarti in the ECE Department have strengthened the collaboration and facilitated the involvement of ECE students in CSP projects in areas such as atmospheric studies using radio wave technology, remote sensing, and astronomical imaging. The recent addition of Prof. Semeter to the ECE faculty has created a stronger link, and continued collaboration remains of mutual benefit to both units.

B. Information Systems and Sciences (ISS)

The ECE department has established a strong, nationally recognized research group in the area of Information Sciences and Systems (ISS). This is evidenced by the fact that almost every ISS faculty member has been awarded the prestigious CAREER award and several faculty members have successfully competed against top institutions in garnering highly coveted MURI awards. ISS faculty members have also been instrumental in bringing the highly competitive Engineering Research Center (ERC) on sub-surface imaging to Boston University, and another ERC’s is currently being contemplated in the area of video networks. Many of the faculty chose BU over competitive offers from higher ranked institutions.

Our most recent addition in this area is Masoud Sharif, who recently received his PhD from CalTech.

Research in ISS deals with the dual aspects of uncertainty and information in physical as well as engineered systems. The group works on applications including biomedical signal and image processing, coding for communication systems, multimedia communication, distributed and mobile computing, sensor networks, and advanced visual communication and entertainment. This area overlaps with the CSE group, and a program in computer networks benefits from this diverse expertise in the Department.

A particular strength of this group has been in establishing a pre-eminent position in the area of sensor networks. Indeed, it is not farfetched to say that, in this particular realm, we are the strongest in the Boston area and favorably viewed in comparison to other nationally recognized groups such as Berkeley, Stanford, UIUC and Michigan. To put this into perspective, an NSF funded workshop on networked sensing, information and control being organized by BU has almost all faculty drawn primarily from these institutions and none from Boston area schools (other than BU). The area of sensor networks—a massive network of tiny sensors capable of measuring, processing and exchanging data over a wireless medium—has immense potential and the envisaged applications range from military surveillance to environmental biology and ecological monitoring. In this context our faculty has an ongoing collaboration with the BU biology department.

Another aspect of this group’s research involves the extraction and interpretation of uncertain/incomplete information in bio-medical imaging contexts. The laboratory has established strong collaborative efforts with MGH and has an active ongoing collaboration with the BME department. A related area of research actively being pursued by our faculty in collaboration with MGH involves understanding the structure of very high dimensional data through information-theoretic methods. This area has recently received significant attention in the context of Bio-Informatics. The ISS group, with its strong emphasis on understanding information & its structure, is a natural home for this research endeavor. Our long-term vision would exploit our unique competitive advantage over other Boston-area schools and establish a first-rate research program in information sciences and its myriad applications ranging from wireless communications, networked sensing, and bio-informatics through active collaboration and well-instituted faculty hires. The continuation of recruitment of new faculty members is essential to consolidation of the program and retention of “star” faculty members.

C. Computer Systems Engineering

Computer systems engineering (CSE) has a special significance as a vital technology for the 21st century with very broad applications. This can be seen, for example, in the three national priorities outlined by the NSF — Nanotechnology, Information Technology, and Bioinformatics. Their confluence lies directly within CSE. Some opportunities include: combining nanotechnology with computing technology on a chip, development of computer systems for bioinformatics and computational biology, application of knowledge engineering to information technology and bioinformatics, and development of embedded systems for communications and sensor networks. The ECE Department has strengths consistent with these opportunities including research in computer architecture, VLSI, fault-tolerant computing, communications and computer networking, embedded systems, and, computational science.

Communications and computer networking lies at the boundary between the ISS group and the CSE group. There is no doubt that networks have dramatically changed our society and are expected to continue to have a significant economic impact and to drive much of electronics and computer technology. Student demand for telecommunication and networking courses has been high, and the Department has recently enhanced the curriculum in this area at both the undergraduate and graduate levels. A number of new
faculty members have established research programs in this area. The Computer Science Department at BU has also targeted computer networks as a strong research thrust, the Department of Manufacturing Engineering has a strong systems group with a related interest in discrete event systems, and the Center for Information System Engineering (CISE) has linked research activities across the campus. Our combined effort has created a strong BU program in this important area.

**VLSI electronics** continues to be an area of fundamental importance since VLSI circuits constitute the principal hardware for computers and embedded systems. Maintaining a strong instructional program in this area is essential for both our degree programs. Application of VLSI electronics to biological sensors is an area of great potential and interests both the ECE and the Biomedical Engineering Departments. The addition of more faculty in this area is essential to meet increased teaching needs, to reduce the burden on the few research productive faculty in this area, and to give this area the critical mass necessary to gain national recognition and competitiveness for research funds.

Other important areas in computer engineering include **embedded systems** and real time software design, **reliable computing**, **design automation**, **asynchronous systems**, **test and diagnosis of computer hardware**, and **multimedia computing**. Research in **computational science** is strong in ECE and is linked with the Center for Computational Science and the Scientific Computing and Visualization Center. Another link offering particularly strong synergistic possibilities with the high-performance computing group is that with the Center for Space Physics, a BU research center with strong links to ECE.

**Collaborative Research with Other BU Departments and Centers**

The ECE Department has strong collegial ties to important Boston University centers, most notably the Photonics Center, the Center for Nanoscience & Nanobiotechnology (CNN), the Center for Information Systems and Engineering (CISE), the Center for Computational Science, the Center for Space Physics, the Center for Subsurface Sensing and Imaging Systems (CenSSIS), and the Center for Cognitive and Neural Systems. We also have strong links with several other departments at Boston University (See Figure 2). Many faculty members have strong extramural ties in larger centers, multi-university initiatives, and industry collaboratives.

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**Figure 2.** Links between the ECE Department and other departments and centers
2.5 Diversity of Faculty, Staff, and Students

2.5.1 Intellectual, Racial, and Gender Diversity in the Department

Faculty and Staff. Of the 44 ECE faculty members, four are women (two tenure-track), two are Hispanic, and one is African American. Of the 13 ECE administrative and technical staff, there are two women and one Hispanic.

Students. As Appendix 5.6 shows, the number of women in our BS program constitute 13% of the student enrollment. In the MS and PhD programs, women represent 13% and 22%, respectively. Hispanics represent approximately 4% of the BS and MS enrollment and less than 1% of the PhD enrollment. There are only 4 African Americans in the BS program and 2 in each of the graduate programs.

2.5.2 Strategy for Enhancing Diversity

Racial and gender diversity in the Department needs to be improved at all levels.

Faculty. We have added two women to the faculty, one in 2002 and one this year as a target of opportunity. In recent years, many women faculty candidates were interviewed and some offers were made but declined. Opportunistic hiring of women and minority faculty must continue, and a proactive and systematic effort to find such candidates via various forums, organizations, and networks must be made. All faculty searches will be held to a high standard of representation of women and minorities in the considered pool. Coordination with other units, including joint and special appointments will be useful.

Student diversity is also inadequate, particularly racial diversity. Since the Department is directly involved in the recruitment of graduate students, it should proactively look for and attract candidates meeting admission criteria, and should effectively use all available fellowships and scholarships. Since the LEAP program has traditionally been an excellent source for women graduate students, it should be enhanced and expanded for this purpose. Links with historically minority schools is another mechanism for accessing a potential pool of graduate students.

Undergraduate diversity is more difficult for us to enhance directly since the Department plays a smaller role in the recruitment process. Emphasis on ECE applications that have traditionally been attractive to women can be a useful mechanism for recruitment. Links with local high schools and participation in various K-12 programs funded by the federal government offer mechanisms for influencing the pool of potential women and minority students.

Community building. The Department will foster an environment that embraces underrepresented groups by providing mentorship and fostering collaborations and mutual support. To this end we will coordinate and cooperate with other organizations in the BU community, including the NSF Centers and WISE (Women in Science and Engineering).

3. Long-Term Goals and Strategies

Electrical engineering and computer systems engineering are fundamental technology disciplines. They address challenging research problems, support important applications, and offer strong opportunities for business development. Innovations from electrical and computer engineering define modern society and support much of the world’s high-tech economy. Personal computers, cellular phones, fiber optic communications and the Internet, medical imaging systems, digital CDs and DVDs, laser materials processing, new energy sources, and modern defense systems are just a few of the many technologies arising from electrical and computer systems engineering.

Electrical engineering and computer systems engineering are also enabling disciplines. They are critical to the development of virtually every field of science, technology, and medicine. Electronic instrumentation for measurements on scales from nanometers to light years, environmental monitoring of pollution, land use and global warming, automatic control systems for industry and transportation, data communications for people, corporations, and governments, computer modeling for economics, DNA, weather, and security are examples of how we support broad areas of inquiry and contributions to human knowledge and welfare.

It is critically important that Boston University maintain an outstanding academic program in the disciplines of ECE. Electrical and computer systems engineering have special significance and relevance as key technologies for the 21st century, where information and systems sciences will be vital to the solution of the significant problems facing society. Other areas of the university benefit from the
technologies and training we provide to research, education, and outreach. And the Massachusetts economy, especially along Route 128/I-93, is strongly dependent on companies and industries rooted in electrical and computer systems engineering. Even the financial services economy of Boston relies on information sciences, communications, and computer systems supported by the disciplines we address. Finally, efficient, effective intelligence and defense systems increasingly rely on electrical and computer systems engineering innovations. Systems are needed to collect data and project force in lieu of putting soldiers and military assets directly at risk.

Our long-term goals and strategies are:

- To propel the ECE Department into the top 30 in the US, and the top 5 among private, liberal-arts universities with an engineering program. This will be accomplished by enhancing the true quality of our educational and research programs and our faculty and student body, and by enhancing our national visibility through a concerted publicity effort. We also aim at becoming number 1 in a few sub-areas of research.

- To continue to focus on a few important areas of excellence (photonics, information systems and sciences, and networked computer systems) that will create outstanding programs of research and innovation while contributing to a strong undergraduate learning experience and cutting edge graduate research. This will require faculty stability and growth and continued University support for curriculum and laboratory development.

- To be aggressive and opportunistic in pursuit of emerging areas of ECE (e.g., semiconductor optoelectronics, biosensing and imaging, quantum information technology, and networked embedded computer systems), by realignment of our programs and selection of new and replacement faculty. Recruitment of new senior faculty can be effective in jump-starting new areas.

- To nurture alumni for increased participation in departmental activities and donation of funds for scholarships and endowed professorships in support of existing or new outstanding faculty.

The ultimate size of the faculty in ten years will be dictated by changes in undergraduate and graduate enrollment patterns and by the faculty success in obtaining research funding that fuels growth. The selection of new faculty has been motivated by the need to (a) strengthen existing research areas to become more competitive at a national level, (b) develop expertise in emerging areas of ECE to keep up with the rapidly-changing face of the profession and play a leading role in shaping future technological advances, and (c) respond to shifting and growing student enrollments at both the undergraduate and graduate levels. We also aim to exploit synergies between our existing research areas and links with other departments and centers at Boston University. We expect a strong rebound in high tech over the next decade and plan to invest wisely now to benefit from these coming opportunities. The continued excellence of our faculty and students will lead to the increased prominence desired for Boston University’s ECE Department.

3.1 Educational Excellence

Vision and Goals for the Undergraduate Programs

Currently we are experiencing declining enrollments in our ECE undergraduate programs while graduate enrollments are increasing. However, a careful examination of ECE enrollments at BU as well as nationally shows that undergraduate enrollment patterns are cyclical and currently we are approaching the bottom of a trough. The next peak would be expected within the next 5 to 10 years. To serve the needs of those undergraduates, we need to ensure that the faculty size is maintained at the current level.

In designing our ECE undergraduate programs at Boston University we have always aspired to strike a balance for our students between:

- Engineering theory and engineering practice
- Technical/scientific education and general/liberal-arts education.
- Preparation for “rank and file” roles and preparation for “leadership” roles.

Given the global growth expected in the electrical & computer engineering workforce in the 21st century and the anticipation that low-tier engineering jobs will continue to migrate out to countries like

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2 The 2004 ASEE Profiles of Engineering Colleges list of departments offering doctoral degrees includes: 85 in electrical engineering, 32 in computer engineering, and 69 in electrical & computer engineering.
China and India, graduates of electrical and computer engineering programs in the US will need to climb up the “leadership food chain” so to speak. It is thus fair to ask how this should affect the three balances we aspire to for our BU graduates.

The balance between engineering theory and engineering practice should continue to play a defining role in our programs. No matter what directions the engineering marketplace takes, there will always be strong demand for individuals who compliment rigorous understanding of theoretical fundamentals with extensive practical knowledge and experience and are committed to maintaining that balance through their commitment to life-long learning. Over the coming years we intend to intensify our efforts to have the curricula of our department’s programs more explicitly equip our students with the skills necessary to maintain the commitment to life-long learning.

The balance between technical education and general education has to remain a hallmark of engineering programs at Boston University not only because the university provides a strong and diverse liberal-arts base but because the engineers of tomorrow are expected to have a greater role as mediators between technology and its effects on society. Currently our students do not receive much guidance in selecting their liberal-arts courses in a manner that compliments their professional aspirations. Should they be required to take an economics course? Should they be required to take a world history course? Should they be required to take a technology and society course?

The balance between preparation for leadership and rank-and-file roles is one that we anticipate will have to be significantly changed over the next decade. Leadership roles are going to be much more important for our future graduates. This is in contrast to an expected diminishment in the more traditional “rank and file” roles (e.g. in design and manufacturing) because of the changing nature of the global marketplace for engineers. Leadership roles include those in research, in innovation, in policy making, in business, in management, etc. This means that there has to be greater emphasis in our undergraduate programs on preparation for the attainment of advanced professional education either within the field or in related areas such as the sciences, business, finance, medicine, and law. How can this be achieved?

- By providing greater in-depth specialization within the existing EE and CSE programs for students who want to go on to conduct research within the traditional EE or CSE areas.
- By providing a new major in “Electrical & Computer Engineering” for students who desire their basic preparation to involve a blend of topics from electrical engineering and from computer engineering. This is suitable for students who either want a broad ECE background to serve them in future careers in fields such as law, business and medicine or those who want to prepare for research in a specialty at the boundaries of the more traditional areas of electrical engineering and computer engineering. The undergraduate major in Electrical & Computer Engineering is a relatively new idea but it has already taken hold in several research universities that BU is competitive with. These include WPI, Duke University, Carnegie Mellon University, Cornell University, and University of Rochester.

ECE is a broad and diverse discipline and some argue that 4 years is not sufficient to attain a sufficient amount of education to create a real professional. We already have a 5-year Combined BS/MS program to encourage our undergraduates to pursue advanced studies in ECE. However, we need to promote this program more actively.

Our vision for how to better serve the learning needs of our students includes a recently initiated effort to aid our students in developing an “integrated view” of ECE as they progress through the various courses. This is to overcome the tendency for knowledge acquired by students to get “compartmentalized” in the minds of our students in accordance with the course in which the knowledge was acquired. Our “integrated view” efforts combat this tendency by having several of our core undergraduate courses explicitly discuss how the knowledge in each particular course relates to a particular type of product – a cellular phone, for example. Our vision is to expand upon this “integrated view” concept over the next 5 to 10 years.

As science and engineering become increasingly global, U.S. scientists and engineers must be able to operate in teams comprised of partners from different nations and cultural backgrounds. We should therefore build on the successful ENG study abroad program and emphasize international programs for the development of global engineers.

ECE is a continually evolving field. We also need to ask ourselves if there are going to be radical changes taking place in the field over the next 10 years. For example, would the dominance of silicon still be assured in 10 years? What would it be replaced by? How would that affect what we emphasize in our basic undergraduate courses? What radical shifts may we anticipate in regards to computers, information processing, or communication? Is the 21st century the century of biology and medicine? If it is, how does
that affect our vision of what an ECE education should be about? These are the kind of questions we need to debate in the coming years to help make ECE education at BU the best it can be.

Our strategic goals for the undergraduate program are:

- To increase the appeal of the undergraduate program by making it more attractive, more flexible, and more relevant to current technology.
- To create a curriculum that strikes a balance between theory and practice, between technical/scientific education and general/liberal-arts education, and between preparation for “rank and file” roles and preparation for leadership roles.
- To provide our students with an opportunity to have a research experience.
- To provide our students with an integrated view of ECE and to equip them with the skills necessary for life-long learning.
- To emphasize international programs for the development of global engineers by building on the successful ENG study abroad program.

**Vision and Goals for Graduate Programs:**

Our goal is to improve our graduate program to a nationally competitive level capable of attracting top students, to provide world-class education in a broad range of topics and to train and prepare students for careers in industry, research, academia, and government. Our long-term goal is to elevate our graduate program to a national ranking robustly in the top 30 in the US with 3 or 4 topical areas of national prominence.

**Program and Student Population.** Cleary, our graduate programs are of high importance. Over 200 graduate students contribute to the research and scholarly excellence of the department and particularly MS students also provide significant tuition income. Therefore, we want to continue to grow our PhD program to a target number of 20 degrees/year (0.5 PhDs per faculty-year awarded) while nurturing and simultaneously maintaining the MS program at more than 100 students enrolled. In order to build our graduate programs, both MS and PhD, it is necessary that we build upon our current strengths and provide education in new and exciting areas. We consider the following as opportunities:

- Develop relevant and exciting degree programs, such as the recently established MS in Photonics and the recently proposed graduate program in materials engineering.
- Build upon interdisciplinary strengths and centers to offer flexible MS programs in crosscutting areas (for example, CS and CSE, EP and Physics or Space Physics, ECE and BME/MED, and ISS and MFG/CISE).
- Seek federal funding to support interdisciplinary as well as international endeavors.

**Student Outcomes.** The current career trend for MS students in industry is appropriate. We would like to see more of our PhD graduates pursuing academic careers. Having BU graduates placed in reputable universities as faculty will help to improve our academic reputation.

**Alumni Relations.** The Department should maintain contact with all former graduate students and keep them abreast with the recent developments. We must provide our ambassadors with fresh information (for example in the form of a departmental newsletter) to allow them to spread the news. While we continue to have the service of our alumni in advisory boards, we also plan to utilize the prolific alumni as role models to encourage our graduate students to set high career goals and pursue academic positions.

**Improved rankings, reputation and perception among peers.** Quite possibly, improving the reputation of our department among our peers and the rankings in published literature will have the most impact in building a successful graduate program. Clearly, improved scholarship and research, as targeted in our departmental strategy, would be the ultimate key to improved reputation. However, proper publicity is also essential especially in reducing the time lag for reputation to develop. Publicity is a team effort and thus in addition to dedicated staff resources and faculty committees, individual faculty members must contribute to this effort by professional service (for example in conferences and technical societies) as well as participation in presentations at peer institutions. Administration could provide encouragement by placing an emphasis on active participation in such endeavors during merit review.
3.2 Research and Scholarly Excellence

1) As mentioned earlier, our strategy for creating a prominent research program has been to focus on a few important research areas. Our long-term plan includes launching a number of large research initiatives in each of these areas.

The following initiatives have been identified:

**Semiconductor Optoelectronics**
Semiconductor optoelectronics has continued to be an enabling technology for numerous applications in next-generation communication and networking, computing, and consumer electronics. A number of ECE faculty have been pioneers in development of optoelectronic devices for production of blue light by use of wide-bandgap semiconductors, generation of long-wavelength infra-red from quantum cascade lasers, design of state-of-the-art LEDs for solid-state lighting, production of laser light from silicon nanostructures for numerous optoelectronic applications, detection of UV for applications in solar-blind detectors, and novel semiconductor structures for single-photon detection. There is strong interest in these applications among funding agencies, such as DARPA, DOE and NSF, and these agencies have funded much of this work. We envision the continuation of this work and the launching of other major collaborative research initiatives in the next 10 years.

**Biosensing and Imaging**
The development of improved sensing modalities and associated processing technologies to extract critical information in biological systems presents a valuable opportunity for extensions and applications of current areas of excellence within ECE. The ECE department has significant expertise and research activity in the development of platforms for biosensing and imaging and associated signal and image processing techniques. Our blossoming research activities in these areas are achieving increased national recognition, as evidenced by their leadership roles in NSF Engineering Research Centers (CenSSIS), the presence of large NIH and DARPA support, the creation of the Center for Nanoscience and Nanobiotechnology, and the increasing joint grant activity with Boston Area medical institutions. Our long-term goal is to expand our research support in these areas, plus exploit the individual excellence of our current ECE research and existing collaborations to pursue multidisciplinary programs in collaboration with other BU departments and partners. Such programs include NIBIB quantum grants, one of which is currently under preparation, MURIs, IGERTs, NSF Partnerships for International Research and Education, NIH/NIBIB training grants and Bioengineering Research Partnerships.

**Quantum Information Technology**
Quantum information, including communication and cryptography, is a rapidly developing cross-disciplinary technology that is based on cutting edge research in photonics, electrical engineering and quantum physics. Three ECE photonics faculty members have developed the world’s first metropolitan quantum cryptographic network, in cooperation with BBN Technology and Harvard University. They are members of a recently funded ARO MURI grant on quantum imaging, which funds investigations of the use of quantum technology in non-invasive, ultra-precise metrology and its applications to biophysics, biochemistry, nanophotonics, and optoelectronics. A fourth ECE faculty member is world-renowned for his work on quantum information theory. This team is in a strong position to lead a major new collaborative research initiative in this area.

**Distributed Information Processing**
The recent progress in development of miniaturized devices capable of being deployed in large numbers for sensing, actuating and communicating in complex environments has created an opportunity for new approaches for monitoring, understanding and control of a diverse range of applications ranging from homeland security to environmental biology. A fundamental challenge in successfully realizing such systems is the development of new capabilities for distributed processing of information in large networks with heavily constrained sensing, communications and processing resources. The ECE department has significant capabilities in this area that have achieved national recognition, as evidenced by NSF and DoD research grants, NSF CAREER awards, organization of NSF-funded international workshops, leadership in MURI efforts, and invited talks at prestigious workshops and conferences. These activities are enhanced by active multidisciplinary collaborations with BU’s Center for Information and Systems Engineering. Our strategic vision will be to strengthen further our leadership role in this area by leading large efforts on NSF and DoD programs such as ERCs and MURIs, plus collaborating with other departments and institutions to pursue distributed information processing opportunities in new applications such as homeland security and biotechnology.

**Networked Embedded Computer Systems**
The success of the Internet in creating a virtual world of interconnected information, processes, and commerce will yield to a world characterized by interconnected and networked physical objects and the availability of a reservoir of storage and computational power via Grid technologies. This intersection of fine-grained data on the state of the physical world (provided by embedded systems) and the shared computational power of the Grid will yield new models for commerce, scientific discoveries, and profound changes in social behavior. These advances will be driven by advances in complex systems analysis, software technology, computer architectures, wireless communication, chip design, and low-bit-rate image coding. This thrust area encompasses core expertise in system and hardware architectures, device design, and computer networks, distributed information processing, software engineering, and multimedia data processing.

2) Significant increase in research funding is necessary if we are to rise to the top tier of ECE Departments.

Although external funding has increased significantly in the last decade, and the average annual new funds per faculty of $267k is acceptable, a significant number of the ECE faculty receive little or no external funding. Although the emphasis on establishing a funded research program has been strong at the Department and College levels for more than a decade, a sizable number of ECE faculty have not competed for funding support, or have repeatedly been unsuccessful. One approach to address this problem has been the promotion of collaborative research projects in which those faculty are embedded in teams with other successful faculty. Facilitation of early retirement for research inactive faculty is another approach, which we have pursued. In any case, the replacements of retiring faculty must be selected based on their likelihood of initiating funded research.

3.3 Increased Diversity of Faculty and Students

The Department is fully committed to build a diverse community of faculty and students. Our strategy is described in Sec. 2.5.2.

4. Short-Term Priorities

Our top three short-term priorities are:

- Increase the appeal of our undergraduate programs:
  - by improving the curriculum to make it more attractive and more relevant to current technology
  - by making the program more flexible
  - by increasing the visibility of the programs.

- Enhance our national and international visibility as a leading ECE department:
  - by pursuing new large collaborative grants (such as NSF and DOD centers); one initiative in each of our three research thrust areas
  - by pursuing several educational and training grants for support of graduate students and curricular development. For example, the photonics group envisions a graduate training grant (NSF and DOE) in the area of materials modeling, growth and characterization
  - by seeking leadership positions for our faculty in professional societies, including editorial positions for key technical journals
  - by seeking international partnership grants, which will establish connections with leading scientific institutions and serve as a mechanism for recruiting outstanding international graduate students.

- Realign and strengthen our partnership with the Photonics Center. As this Center redefines its academic mission, the ECE Department, which has more than 10 faculty members with research activity in photonics, should play an increased role in the following areas:
  - Integrate relevant ECE research initiatives with the Center.
  - Integrate the Center into the ECE educational program and support the academic mission of the Center. For example, market the MS in Photonics program and develop new outreach and distance learning programs in photonics in coordination with the Center.
  - Help enhance the reputation of the Center in the academic community.
5. Appendices

Appendix 5.1 History of Faculty Turnover

History of faculty size (FTE), including additions (blue) and attrition (red). Affiliate faculty and research faculty with no teaching responsibilities are not included in this chart.
Appendix 5.2  History of Research Funding

New research grants and contracts (the dark bars represent grants and contracts for which the principal investigators were ECE faculty; the light bars represent the share of ECE faculty in grants and contracts for which the PI are from other departments).

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<th>Year</th>
<th>NSF</th>
<th>DOD</th>
<th>NIH</th>
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| 2000-2001 | $1,891 | $4,401 | $421 | $151 | $150 | $7,014 |
| 2001-2002 | 27.0% | 62.8% | 6.0% | 2.1% | 2.1% | $5,238 |
| 2002-2003 | $2,401 | $2,402 | $80 | $268 | $87 | $7,467 |
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| 2000-2001 | $1,891 | $4,401 | $421 | $151 | $150 | $7,014 |
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| 2002-2003 | $2,401 | $2,402 | $80 | $268 | $87 | $7,467 |
| 2003-2004 | $3,631 | $3,091 | $632 | $76 | $37 | $6,330 |
| 2004-2005 | $2,710 | $2,586 | $818 | $216 | $- | $5,161 |

ECE Strategic Plan – 2006

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Appendix 5.3 History of Student Enrollment

Appendix 5.4 History of Undergraduate Student Enrollment in EE and CSE Programs
Appendix 5.5 History of Degrees Awarded
## Appendix 5.6  Gender, Minorities, and International Student Enrollment Trends

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