The History of Computer Engineering
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A. What is Computer Engineering Today?
Computer Engineering at USC deals with the design, development, testing, and evaluation of complex components, systems and networks. These systems are usually electronic, but may also include other forms of transmission of information such as optics. These systems are primarily digital, though, as one progresses down the physical implementation hierarchy, most components appear to be analog or quantum. Research in Computer Engineering strives to achieve higher efficiencies in the systems and components that are built as well as in the design process. Efficiency is used here in a generic way and in specific cases may refer to such concepts as cost, performance, power, availability, reliability and connectivity. Our research is focused in three main areas: Computer Architecture and Parallel Processing; Design and Analysis of Computer and Sensor Networks and their Protocols; and finally Design, Computer Aided Design, Test and Verification of VLSI circuits and systems.

B. Who are the players and when did they come to USC
Table I indicates the time line of when tenured or tenured-track faculty were hired into the EE department with the understanding that they would initially work in the areas of computing or computers. Here we see that the first six members of this group were Irving Reed, Bob McGhee, George Bekey, Mel Breuer, Bill Pratt and Seymour Ginsburg. With this core group, along with Ed Blum from the math department, in 1969 a Computer Science Program was formed. Eventually Bekey and Ginsburg moved to the Computer Science Department (CSCI), established in 1976, McGhee transferred to the Midwest, and Pratt went forth to commercialize his work in image processing. From 1969-1976 the department hired 18 individuals, about half of who could be classified as computer engineers, and half as computer scientists. Of these, only six remained for more than six years. Finally, with the establishment of CSCI and the concurrent establishment of a Computer Engineering Division (CEng) with the Electrical Engineering Department, the hiring frenzy ended, and the focus was placed on individuals who were more oriented to the visions expounded by computer engineering, though many of the subsequent hires had degrees in computer science.

One focus for the newly reformulated group was the area of computer networks. This led to the hiring of John Silvester, Alex Thomasion and Jimmy Yee in the 1980’s. Since that time, CSCI, the Information Sciences Institute (ISI) and CEng have continued to expand in this important area, each entity hiring several stellar researchers such as Debra Estrin and Joe Bannister.

In addition, after the formation of CSCI, CEng focused once again on its core areas of interests, namely computer architecture and the VLSI issues of design, CAD, verification and test. The VLSI effort was enhanced with the arrival of Alice Parker, Sarma Sastry, Massoud Pedram, Sandeep Gupta, Peter Beerel and Won Namgoong. New architecture
folks included Dan Moldovan, C. Raghavendra, Viktor Prasanna, Jean-Luc Gaudiot, Michel Dubois, Kai Hwang, Alvin Despain, Timothy Pinkston and most recently Murali Annavarum.

Table I lists the 53 individuals who, at one time, had CEng/EE as their home department. Of these, 14 remain in this category, and three have CSCI as their home department.

C. The Surrounding Landscape
The College of Engineering at USC was established in 1927 and renames as a School in 1950. While it is not clear when the Electrical Engineering Department was established, the first B.S. degree in Electrical Engineering was awarded in 1911. The first computer on campus may have been a used Model 102D Scientific Digital Computer that arrived in 1957. In the early 1960's, the SoE established the USC System Simulation Laboratory under the direction of George Bekey and Robert McGhee. The principal hardware consisted of an IBM 1620 that had 20,000 decimal digits of core storage and 2 million digits of disc. It took 400 µsec. to add two three-digit decimal numbers. In addition, there

Table I(a): Tenure and Tenure-Track Faculty in EE with Focus on Computers and/or Computing 1963-1983

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<td>Emeritus</td>
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</table>
was a Beckman 2132 analog computer with servo-set potentiometers and 100 amplifiers. These two units communicated via conversion equipment consisting of:

1. A solid-state A/D converter with a maximum sampling rate of 6000 points/second.
2. A solid-state multiplexer providing 10 channels of A/D conversion.
3. Ten D/A converters, consisting of digitally set relay attenuators with a maximum conversion rate of 200 points/second.

In the late 1960’s, the 1620 was replaced by an IBM 360/44 that had 64K words of core memory. Soon afterward, there was a proliferation of new machine purchases and gifts, the details of which are too numerous to document. One important gift made in the mid 1980’s was made by Alan Hanover, CEO of Viewlogic Systems Inc., who contributed 20 IBM PC and Viewlogic CAD software for logic design.

In its early years, the focus of the School was primarily on teaching rather than research. In the early 1960’s, the EE Department took a radical turn in culture and focus under the strong leadership of a new department chair, Zohrab Kaprielian. Zohrab’s vision was to turn, first the Department, then the School of Engineering (SoE), and finally the
University into an elite research entity rather than a teaching entity. By later becoming the Dean of Engineering and subsequently the University Provost, he was able to lay the foundations for his dreams which have recently all come true. In the early 1960’s, the Department was just beginning to develop a program that encompassed computing and computers. The evolution of this activity since this time is illustrated in a series of tables dealing with the evolution and time-line of classes (see Appendices A and B) and Figure 1.

![Figure 1: Genesis of Computer Engineering Division](image)

In the late 1960’s the field of computing was gaining much attention and elements of a new and dynamic breed of individuals emerged, affectionately referred to as computer engineers or scientists. In response to this national and international movement, in 1969 the School of Engineering and the Mathematics Department formed a Computer Science Program for graduate students, initially administered by Jack Munushian. To a large degree, this program consisted of classes that were already being taught, and faculty whom were already at USC. This minor reorganization was a positive step in our evolution, since it helped to focus attention on the importance and unique aspects of computing both in the world and within USC and electrical engineering.

Soon after becoming Dean, Kaprielian carried out several major reorganizations, one of which occurred in 1971 and included the partitioning of the EE Department into two administrative entities, namely EE-Electrophysics (EE-EP) and EE-Systems (EE-S). EE-EP areas of focus included subjects such as integrated circuits and their fabrication, solid-state devices, optics and optical devices, quantum effects and devices, lasers, plasmas and power systems. Many of their faculty were experimentalists and/or had doctoral degrees in physics. EE-S focused on control systems, communication and information theory and systems, signal and image processing algorithms and systems, and computer engineering (CEng). During this transition period, CEng included a wide array of subjects such as theory of computation, hardware and software, circuits and systems. The partitioning of the department may have had several benefits, but arguably, it had a negative effect on CEng, the most significant of which was to “separate” the circuits and device folks from the systems folks, as well as experimentalist from non-experimentalist.
In response to the rapid expansion of the field of computer science, in 1976 the SoE expanded their focus on computing by forming the Computer Science Department (CSCI) under the chairmanship of Per Brinch-Hansen. Undergraduates would receive their degrees from the College; graduate students from the Graduate School. At this time, difficult decisions faced the School and the faculty, namely who should be attached to CSCI as their home department, and which classes should be listed as EE, which as Math and which as CSCI? As it turned out, courses that can most simply be described as “hardware” remained in CEng, and “software and theory” moved to CSCI along with the following faculty members: Seymour Ginsberg, Ellis Horowitz, Rick Carlson, Erica Rounds and David Russell. Those who stayed in EE included Irving Reed, George Bekey, Melvin Breuer, John Hayes, Art Friedman, Harry Andrews, Ram Nevatia and Kwang Kim.

Again, the formation of an entity focusing on computing was an outstanding decision, but as so many other universities have encountered, it leads to some divisions and lost opportunities. One significant detrimental effect of separating CEng from CSCI is from the outside, one sometimes is not aware of both entities. Therefore, a student looking at the CSCI faculty might conclude that USC has a weak program in computer architecture, when in fact we do not. In any event, in 1986 George Bekey, who had formerly been chair of the EE-S department, was called upon to become chair of CSCI. Subsequently he moved his research program in robotics from CEng to CSCI along with two EE faculty members, namely Kenneth Goldberg and Suhkon Lee. Soon after that, Ram Nevatia moved his AI/Vision group from CEng to CSCI, along with Gerard Medioni and Keith Price.

In 1972 the School of Engineering (SoE) created the Information Sciences Institute (ISI). This institute, located at the Marina del Rey, CA, was established under the leadership of Keith Uncapher, and many of the initial researchers were from the RAND Corporation. At that time, their primary source of funding was from the United States' Defense Advanced Research Projects Agency (DARPA). The Institutes’ focus was and remains on a broad spectrum of information processing research such as artificial intelligence, the development of advanced computers, VLSI, and communication technology and systems. Their numerous accomplishments are well known in the computing community, and include grid computing, early development and administration of the Internet, and MOSIS. In addition, many of their staff, such as Bill Athas and Jeff Draper, teach or have taught CSCI and CEng classes. The research and teaching programs in CEng and CSCI are greatly strengthened by the collaboration among these three entities.

D. Introduction to Computer Engineering
As mentioned above, Kaprielian brought a new vision to the School and way of doing business. One of his ideas was to seed the department with stars, and then develop breadth via new young hires. In the area of computers, he brought in Irving Reed (h 1963), maybe best known today for his work in communication theory, such as the Reed-Solomon Code, and the Reed-Muller Code. However, Reed had already made major contributions in the early development of computer technology while at MIT and Lincoln Labs, such as his work on micro-coding, symbolic and RTL digital design, and the MADDIDA computer. A year later George Bekey (h 1964) was hired. He came from UCLA where he worked with the late Walter Karplus on hybrid computers. Previously George had established a successful carrier as VP of Engineering at Computer Associates, a company that pioneered hybrid computation. As just one example of
Zohrab’s astuteness, both of these individuals eventually became members of the National Academy of Engineering.

Unfortunately, both of these computer gurus soon became interested in other areas; Reed in communication and Bekey in estimation theory, then bioengineering, then robotics and finally computer science. This put a great deal of pressure on two young assistant professors, Robert McGhee (h 1963) and Melvin Breuer (h 1965). With the early departure of McGhee, Kaprielian gave Breuer much of the responsibility to build the computer engineering arm of the department. Initially, to teach and expand its class offerings, the computer group relied heavily on recent USC Ph.D. graduates, such as Bill Pratt, George Mager, Bill Meisel, Jim Chandler, Bob Kashef and Harry Andrews. After starting what became one of the first and premiere University signal and image-processing institutes (SIPI), Pratt and Andrews eventually left USC to start successful graphics companies. Dr. Andrews later became Senior VP at 3M Corporation, while Pratt went on to hold senior positions at Compression Labs, Sun Microsystems and Photon Dynamics. Other new hires included Robert Tooper, an expert in numerical analysis, Phil Gilbert, a software guru, and Alan Zobrist who focused on AI. Part time help also came from industry, such as Lowell Amdahl (the brother of Gene) from TRW, Joe Smith from Rand Corp., and Marv Perlman from JPL. But, of course, the real goal was to build a first class research group. Two areas of focus were identified. One being computer architecture, the second digital testing and computer aided design. The first area was where most of the current action took place at other universities; the second area was a gamble based on the premise that this area will soon be an essential part of computer development. To round out the program, theory was also selected as being essential. Due, however, to a lack of financial resources and possibly foresight, the areas of circuits and software were put on hold.

The area of theory was again addressed using the Kaprielian axiom of hiring the best; thus the late Seymour Ginsburg (h 1967) was brought in and developed courses in the theory of automata, formal languages and data-bases.

D.1 Switching Theory, Test and Computer Aided Design
The areas of testing, switching theory and CAD got a booster shot with the appointment of one star, namely Art Friedman (h 1972), and one future star, namely John Hayes (h 1972). Art, who had studied under Louis Unger at Colombia, was part of the famed Menon-Friedman Bell Labs team who had written the first definitive work on switching theory since Zvi Kohavi’s *magnum opus* Switching and Finite Automata Theory, had produced an early book on testing of digital logic, and had flooded the journals with outstanding papers on switching theory. John Hayes, who had recently graduated from the University of Illinois, also joined our group in 1972. While John’s initial interests were in switching theory and testing, he soon broadened his interests and research, and developed classes in both CAD and then computer architecture - an area in which he has published several books. John also established the first micro-processing classes and labs at USC. During this period, we established an outstanding program, second to none, in switching theory, testing, and computer aided-design of digital systems. Israel Koren was part of this group for one year prior to his tenure at the University of Massachusetts. Robert Kashef and William Meisel were also strong contributors to our work in switching theory. During this period, research funding came predominantly from NSF and the Office of Naval Research.
Alice Parker received her Ph.D. from North Carolina State University and went on to carry out pioneering work in automatic synthesis, simulation and verification. In 1981, we were able to attract Alice away from CMU, thus providing us with a strong foundation in high-level synthesis. Soon she expanded her interests into CAD frameworks and databases. Alice, along with two of her Ph.D. students, David Knapp and George Granacki, developed the Advanced Design Automation System (ADAM) and the Design Data Structure (DDS). Much of their results were later incorporated into commercial CAD systems.

In the 1980s, the test/CAD group was fortunate to receive DARPA funding, and thus able to produce many prototype test related system. Fundamental results were developed related to topics such as design-for-testability (DFT) and built-in self-test (BIST) architectures, test controllers, test scheduling, and scan-chain organization. The test technology faculty was further strengthened by the acquisition of Sandeep Gupta (h 1991), who also branched out into other areas, such as VLSI and networks, but that is another story. Gupta and Breuer have worked together developing several revolutionary results related to testing VLSI circuits, such as those associated with ground-bounce due to internal switching, crosstalk noise, process variation, error-tolerance and performance tolerance.

Because several of our faculty moved away from traditional design automation issues and into areas such as testing and/or administration, a need emerged to hire someone who was interested in traditional CAD issues, but with a focus on current and future generations of computing technologies. The answer came in the form of Massoud Pedram (h 1991) from UC Berkeley, a student of Ernie Kuh. Massoud’s background was primarily in physical CAD, but soon mastered the areas of synthesis and verification, and lead our groups focus on issues of logic and register-transfer level synthesis, low power electronics and design, noise and timing analysis in CMOS VLSI circuits, and system-on-chip design. Finally, in 1994, Peter Beerel, a student of Teresa Meng at Stanford, joined our group, and his interests include computer-aided design of asynchronous and mixed synchronous/asynchronous VLSI systems, as well as formal verification of communication protocols. Peter’s work is both theoretical and practical (commercial), and has allowed him to develop several important patents and ties with start-up companies, such as Fulcrum Microsystems.

While not in our original focus, the emergence of VLSI as popularized by Mead/Conway in the 1980’s thrust this area onto the CAD/switching theory group. Initial technical design help came from John Nelson who training at Caltech, as well as other folks in industry. However, under the leadership of Alice Parker, who quickly became proficient in this area, we were able to develop an enormously successful program. Almost all new faculty joining the group now took on the responsibility of contributing to this program, as it is obviously strongly tied to logic and CAD. So eventually, Viktor Prasanna, Massoud Pedram, Sandeep Gupta, Alice Parker and Peter Beerel became the key instructors in our VLSI initiative. Fortunately, the ISI program, including the MOSIS program, is administered under the USC School of Engineering. This made it possible for many of our graduate students to receive RAships with ISI researchers, as well as allow some of their staff to teach in our VLSI program. Some of these folks included Bill Athas, now a Fellow at Apple, Jeff Draper, and John Granacki. In 1995, we hired our first “circuits” person in the group, namely Won Namgong, again from Stanford. Won’s background included both digital and analog design, with applications to communication systems. However, we did not have to wait for Won before building VLSI systems. Returning to
the beginning of this story, in the 1980’s Irving Reed’s group, under the leadership of Trieu-Kien Troung, an adjunct professor and member of the technical staff at JPL, developed new VLSI driven algorithms for several communication theory problems, and successfully implemented each algorithm as a VLSI chip. (See for example, "A VLSI Design of a Pipeline Reed-Solomon Decoder," IEEE Trans. on Computers, May 1985)

D.2 Computer Architecture and Systems
Subsequent to establishing the switching-theory/CAD group, our focus turned to the area of computer architecture, which in the late 60’s was a field populated by very few senior academics. Thus, initially we focused on hiring the young and brightest candidates available. Our first five architects, all recent graduates, were Dan Moldovan (h 1982), C. Raghavendra (h 1982), Jean-Luc Gaudiot (h 1983), Michael Dubois (h 1984) and Viktor Prasanna (h 1983). Later, two senior faculty were acquired, namely Kai Hwang (h 1985) and Alvin Despain (h 1989). Later Timothy Pinkston (h 1993) joined this group, and most recently, Murali Annavaram (h 2007).

Each of these individuals brought a unique and important attribute to our program. While our hiring criterion is usually based on the principle of “the best and brightest”, we have been fortunately to also find individuals with somewhat diverse interests.

A graduate from Columbia University, Moldovan’s background was in controls, but once at USC he focused on machine translation techniques and systems, parallel processing systems for artificial intelligence, logic programming, image understanding, and design of parallel computer algorithms and architectures. He is well known for the Semantic Network Array Processor (SNAP), a coprocessor attached to a SUN host computer. It combines architectural features such as marker passing, associative processing, and cellular array processing for reasoning on semantic networks.

Raghavendra, who studied under Al Avizienis at UCLA, focused on fault-tolerant computing and interconnection networks, but soon broadened his interests to include computer architectures and more recently, computer networks. These areas complemented our other activities in switching theory and testing.

Gaudiot, a student of Milos Ercegovac at UCLA, was primarily interested in novel computer architectures, such as data-flow machines, fault-tolerant multiprocessors, and parallel logic programming systems.

Dubois joined our faculty in 1984, after more than two years in industry, having received a PhD degree in Electrical Engineering from Purdue University under the tutelage of Faye Briggs. He broadened and strengthened our program in parallel architectures by emphasizing multiprocessor memory systems and general-purpose multiprocessor architectures. His seminal research work on cache coherence and logical properties of multiprocessor memory systems in the 1980’s eventually led to the definition of memory consistency models, which today are part of all instruction-set architecture definitions. At the beginning of the 1990’s he developed the first FPGA-based configurable hardware platform to rapidly prototype multiprocessor architectures.

Finally, Prasanna, a student of Ja’ Ja’ at Penn State, came to USC with a background in computer science, and strong interests in computational complexity, and helped solidify our coverage of parallel architectures and algorithms. His interests have since greatly
expanded into the areas of high performance computing, parallel and distributed systems, reconfigurable computing, network computing and embedded systems.

The acquisition of Hwang and Despain helped turn a new page in the direction of the architecture group. At this time, Hwang had developed a successful research program in supercomputers, had published several popular books, and was a founding co-editor in chief of the Journal of Parallel and Distributed Computing. Despain arrived at USC with a large contract from DARPA to design and build Prolog based compilers, machines and associated CAD tools. He was an advocate of the “tall-thin-man” design paradigm.

Subsequent to this Pinkston, a student of Michael Flynn at Stanford University, joined our group and early on established the SMART Interconnects Group, developing high performance interconnection networks for multiprocessor systems based on advanced architectural techniques and emerging optical/photonic technologies. Our most recent addition to this area is Annavaram, who received his Ph.D. in 2001 from the University of Michigan, and subsequently worked at both Intel and Nokia. Thus Murali comes to us with valuable real-world experience. His primary interests are in 3D stacking and mobiquitous computing.

To summarize our evolution in this broad area called computer architecture, our initial vision in the 80’s and early 90’s was that parallel architectures were the future of computing. In the second half of the 1990’s, because the importance of parallel architectures was waning, faculty interests expanded into different directions. This is illustrated by Dubois’ interests in micro-architectures; Prasanna’s emersion into configurable computing; Hwang’s ventures into grid and pervasive computing, and then into security; Pinkston’s investigations into computer networks; and Raghavendra’s work in communication networks. Now, where the complexity of designing still higher performance multi-thread processors with deep pipelines has started to give way to more simple multi-core chips, there is a refocusing on parallel architectures and more generally on the impact of technology on architecture. This in turn has lead to an increased collaboration with the CAD/VLSI group. This is natural as we are first and foremost electrical engineers.

D.3 Software and theory
Our initial hire in an area that is clearly associated with computer science was Seymour Ginsburg (h 1967), who was already well known for his work on automata theory, languages and for his endeavors into AFL theory. Breuer and Ginsburg were the key faculty in advocating for the development of more diversity and autonomy for the field of computers and computation within the department. Subsequently, R. Tooper (h 1969), Phil Gilbert (h 1970) and Al Zobrist (h 1971) joined the department, the former specializing in numerical analysis, Phil in compilers and operating systems, and AI in artificial intelligence. Our next big success was attracting Ellis Horowitz (h 1973), who later became one of the key leaders in the development of computer science at USC, plus the author of several important text, probably the best known being Fundamentals of Data Structures, and Fundamentals of Computer Algorithms. Partly in response to a tremendous demand by local industry, such as Hughes Aircraft Company, TRW, and the Aerospace Corporation, as well as the general student population, the department then went on a hiring spree to build up a faculty that could offer a large array of fundamental and advanced classes in non-EE oriented computing. This resulted in the hiring of Tom Hibbert (h 1973), Armond Cremers (h 1974), Erica Rounds (h 1974), and Dave Russell (h 1975). Finally, in 1976, these individuals, if still at USC, left CEng and
became the initial faculty of CSCI. While software and the theory of computation remain fundamental parts of computer engineering, most of the research carried out in these areas, and classes offered to our students, are provided by the Computer Science Department. Similarly, CEng provides the “hardware” classes needed by computer science students.

D.4 Robotics and Image Processing
In the early 1970’s new application oriented fields evolved in the area of computer engineering, such as robotics, image processing and computer networks. These areas were inherently multi-disciplinary, and thus often turf battles arose as to where these areas would reside. For example, initially, our image processing group consisted of Keith Price, a research professor, Ram Nevatia (h 1975) and Gerard Medioni (h 1987), but in 1992 this program was transferred to the Computer Science Department.

The robotics area started in the Computer Engineering Group in the early 1960’s under the leadership of George Bekey. This development was due in part with Bekey’s collaboration with the famous Belgrade robotics guru Rajko Tomovic. Barry Soroka (h 1981), Sukhon Lee (h 1984) and Kenneth Y. Goldberg (h 1992) joined this group. Goldberg’s received his Ph.D. at CMU, and his research focus was on robotics and industrial automation; S-K Lee’s main interests were also in robotics and automation, in addition to neural networks and intelligent systems; and Soroka, who received his Ph.D. in Computer Science from the University of Pennsylvania, was a leading authority on the design and implementation of robotic languages and systems. Bekey became chair of CSCI in 1986, and unfortunately, in the early 1990’s moved the robotics program to the Computer Science Department. This area and group has blossomed over the last 15 years. Bekey is the founding editor of the IEEE Transactions on Robotics and Automation.

D.4 Networks, sensors, wireless and ad hoc
In 1979 John Silvester (h 1979), a student of Leonard Kleinrock at UCLA, joined our faculty and helped initiate a program in Computer Networks. He was soon joined by Alex Thomasian (h 1980). Over the next 20 years this program experience tremendous growth and prestige, and eventually spanned over four organizations, namely Computer Engineering, the Communication Theory group of EE-S, Computer Science and ISI. Just prior to the 2000 high-tech stock bust, we had over 10 individuals involved in teaching classes in our networks program, and the total enrollment of fall, spring and summer for one of our networks classes exceeded 450 students. Over the years the following outstanding individuals joined this group: Toshi Minora (h 1980), Jimmy Yee (h 1986), Ahmed Helmy (h 1999), Bhaskar Krishnamachari (h 2002), Psounis Konstantinos (h 2003) and Rahul Jain (h 2008). Note that this group is only a part of our USC SoE effort in networks, since they are several other faculty members in the Computer Science Department and at the ISI. Most of the classes in this area are jointly listed and taught by the faculties in the four areas listed above. The classes shown in Table Evolution of NETWORK (Appendix pp. 9-10) are only those that are under the direct control of EE-S.

The evolution of our work in this area mirrors in part the topics seen in our course descriptions. These include basic mathematical models associated with network theory, such as queueing theory, Markov chains, and graph and other models associated with capacity, flow, and topology. This fundamental work was soon expanded to cover more macro-models dealing with system performance and protocols. These concepts were then adapted to deal with specific families of networks, such as local area networks.
(LANs) and wide area networks (WANs). More recently, several of the faculty have focused on wireless networks, mobile networks and sensor networks.

E. Degrees offered
In response to student desires and trends in the needs of industry, the EE and CSCI departments have individually and/or collectively created a family of academic programs. One of the most popular, created in 1991 was the BS in Computer Engineering and Computer Science (CECS). This program includes a sufficient selection of technical courses to justify being a BS rather than a BA degree, as well as a reduced (compared to EE) focus on electronics and a larger focus on computing. There are periods when the CECS, and undergraduate CSCI and EE programs all have about the same enrollments. Other degrees offered are listed in Table II.

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<th>Degree Description</th>
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<td>1981</td>
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<td>Doctor of Philosophy in Computer Engineering</td>
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<tr>
<td>BS in Computer Engineering and Computer Science (CECS)</td>
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<td>Master of Science in Electrical Engineering (Computer Networks)</td>
<td>1993</td>
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<tr>
<td>Master of Science in Electrical Engineering (VLSI Design)</td>
<td>1993</td>
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F. Course offering
Appendix A consists of a set of charts that indicate the evolution of the courses offered in computer engineering organized by topics. The courses are color-coded to make it easier to follow the changes made to a course. Some changes are minor, usually indicated by using the term “modified.” The courses are organized under the following major topics.
- Logic design and switching theory
- Digital design
- Analog and hybrid computation
- Computer architecture and systems
- VLSI design
- CAD and testing
- Networks
- Robotics
- Programming and software

Appendix B indicates the evolution of computer engineering by year. In most cases, the information has been extracted from either the University Catalogue, the School Bulletin or the EE Department Bulletin. Indicated in this section are the year when course were first introduced and a brief description of the course, as well as when courses were modified. Also listed are the year faculty members are first listed; these dates are usually one year after someone actually joins the Trojan family.

G. Milestones
Appendix C indicates some of the important milestones and achievements of our faculty over the past 40 years.