COMPUTER ENGINEERING

www.ece.iastate.edu (http://www.ece.iastate.edu)

Administered by the Department of Electrical and Computer Engineering

For the undergraduate curriculum in computer engineering leading to the degree Bachelor of Science. The Computer Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The Department of Electrical and Computer Engineering (ECpE) at Iowa State University provides undergraduate students with the opportunity to learn electrical and computer engineering fundamentals, study applications of the most recent advances in state-of-the-art technologies, and to prepare for the practice of computer engineering. The student-faculty interaction necessary to realize this opportunity occurs within an environment that is motivated by the principle that excellence in undergraduate education is enhanced by an integrated commitment to successful, long-term research and outreach programs.

The computer engineering curriculum offers focus areas in software systems, embedded systems, networking, information security, computer architecture, and VLSI.

Students also may take elective courses in control systems, electromagnetics, microelectronics, VLSI, power systems, and communications and signal processing.

The program objectives for the computer engineering programs describe accomplishments that graduates are expected to attain within five years after graduation. Graduates will have applied their expertise to contemporary problem solving, be engaged professionally, have continued to learn and adapt, and have contributed to their organizations through leadership and teamwork. More specifically, the objectives for expertise, engagement, learning, leadership and teamwork are defined below for each program.

The objectives of the computer engineering program at Iowa State University are:

- Graduates, within five years of graduation, should demonstrate peer-recognized **expertise** together with the ability to articulate that expertise and use it for contemporary problem solving in the analysis, design, and evaluation of computer and software systems, including system integration and implementation.
- Graduates, within five years of graduation, should demonstrate **engagement** in the engineering profession, locally and globally, by contributing to the ethical, competent, and creative practice of engineering or other professional careers.
- Graduates, within five years of graduation, should demonstrate sustained **learning** and adapting to a constantly changing field through graduate work, professional development, and self study.
- Graduates, within five years of graduation, should demonstrate **leadership** and initiative to ethically advance professional and organizational goals, facilitate the achievements of others, and obtain substantive results.
- Graduates, within five years of graduation, should demonstrate a commitment to **teamwork** while working with others of diverse cultural and interdisciplinary backgrounds.

As a complement to the instructional activity, the ECpE department provides opportunities for each student to have experience with broadening activities. Through the cooperative education and internship program, students have the opportunity to gain practical industry experience. Students have the opportunity to participate in advanced research activities, and through international exchange programs, students learn about engineering practices in other parts of the world. Well-qualified juniors and seniors in computer engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue both the Bachelor of Science and Master of Science, the Bachelor of Science and Master of Business Administration, or the Bachelor of Science and Master of Engineering degrees.

Students are required to prepare and to maintain a portfolio of their technical and non-technical skills. This portfolio is evaluated for student preparation during the student's curriculum planning process. Results of the evaluation are used to advise students of core strengths and weaknesses.

Curriculum in Computer Engineering

Administered by the Department of Electrical and Computer Engineering.

Leading to the degree Bachelor of Science.

Total credits required: 127
Any transfer credit courses applied to the degree program require a grade of C or better (but will not be calculated into the ISU cumulative GPA, Basic Program GPA or Core GPA). See also Basic Program and Special Programs.
Note: Department does not allow Pass/Not Pass credits to be used to meet graduation requirements.
International Perspectives: 3 cr. [1]
U.S. Diversity: 3 cr. [1]
Communication Proficiency/Library requirement:

ENGL 150	Critical Thinking and Communication (Must have a C or better in this course)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)	3
LIB 160	Information Literacy	1
One of the following:		3

ENGL 314	Technical Communication (C or better in this course)	
ENGL 309	Proposal and Report Writing (C or better in this course)	

General Education Electives: 15 cr. [3]

Complete minimum of 6 cr. from Approved General Education Component at 300- or higher level. Complete additional 9 cr. from Approved General Education Component.

Basic Program: 27 cr.
A minimum GPA of 2.00 required for this set of courses, including any transfer courses (please note that transfer course grades will not be calculated into the Basic Program GPA). See Requirement for Entry into Professional Program in College of Engineering Overview section.

CHEM 167	General Chemistry for Engineering Students	4
or CHEM 177	General Chemistry I	
ENGL 150	Critical Thinking and Communication (Must have a C or better in this course)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)	3
ENGR 101	Engineering Orientation	R
CPR E 185	Introduction to Computer Engineering and Problem Solving I [2]	3
LIB 160	Information Literacy	1
MATH 165	Calculus I	4
MATH 166	Calculus II	4
PHYS 221	Introduction to Classical Physics I	5
Total Credits		27

Math and Physical Science: 20 cr.

COM S 227	Introduction to Object-oriented Programming	4
COM S 228	Introduction to Data Structures	3
MATH 265	Calculus III	4
MATH 267	Elementary Differential Equations and Laplace Transforms	4
PHYS 222	Introduction to Classical Physics II	5
Total Credits		20

Computer Engineering Core: 33 cr.
(A minimum GPA of 2.00 required for this set of courses, including any transfer courses; please note that transfer course grades will not be calculated into the Core GPA).

CPR E 281	Digital Logic	4
CPR E 288	Embedded Systems I: Introduction	4
CPR E 308	Operating Systems: Principles and Practice	4
CPR E 310	Theoretical Foundations of Computer Engineering	3
CPR E 381	Computer Organization and Assembly Level Programming	4
COM S 309	Software Development Practices	3
CPR E 315	Applications of Algorithms in Computer Engineering	3
or COM S 311	Design and Analysis of Algorithms	
E E 201	Electric Circuits	4
E E 230	Electronic Circuits and Systems	4
Total Credits		33

Other Remaining Courses: 32 cr.

CPR E 491	Senior Design Project I and Professionalism	3
CPR E 492	Senior Design Project II	2
STAT 330	Probability and Statistics for Computer Science	3
One of the following:		3
ENGL 314	Technical Communication (C or better in this course)	
ENGL 309	Proposal and Report Writing (C or better in this course)	
Computer Science course [3]		3
Computer Engineering [3]		6
Technical Electives [3]		9
Electrical Engineering course [3]		3
Total Credits		32

Seminar/Co-op/Internships:

CPR E 166	Professional Programs Orientation	R
CPR E 294	Program Discovery	R
CPR E 394	Program Exploration	R
CPR E 494	Portfolio Assessment	R

Co-op or internship is optional.

Outcomes Assessment - Students are required to prepare and to maintain a portfolio of their technical and non-technical skills. This portfolio is evaluated for student preparation during the student's curriculum planning process. Results of the evaluation are used to advise students of core strengths and weaknesses.

Transfer Credit Requirements

The degree program must include a minimum of 30 credits at the 300-level or above in professional and technical courses earned at ISU in order to receive a B.S. in computer engineering. These 30 credits must include CPR E 491 Senior Design Project I and Professionalism, CPR E 492 Senior Design Project II, and credits in the core professional curriculum and/or in technical electives. The Electrical and Computer Engineering Department requires a grade of C or better for any transfer credit course that is applied to the degree program.

1. These university requirements will add to the minimum credits of the program unless the university-approved courses are also approved

by the department to meet other course requirements within the degree program. U.S. diversity and international perspectives courses may not be taken Pass/Not Pass, but are used to meet the general education electives.

2. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.
3. From department approved lists. (http://www.ece.iastate.edu/academics/bachelors-degree-requirements)

See also: A 4-year plan of study grid showing course template by semester.

Note: International perspectives and U.S. diversity courses are used to meet the general education electives.

Computer Engineering, B.S.

First Year

Fall	Credits	Spring	Credits
CHEM 167	4	COM S 227	4
CPR E 185	3	CPR E 166	0
ENGL 150	3	MATH 166	4
ENGR 101	0	PHYS 221	5
LIB 160	1	General Education Elective	3
MATH 165	4		
	15		16

Second Year

Fall	Credits	Spring	Credits
CPR E 281	4	CPR E 288	4
COM S 228	3	ENGL 250	3
MATH 265	4	MATH 267	4
PHYS 222	5	E E 201	4
CPR E 294	0		
	16		15

Third Year

Fall	Credits	Spring	Credits
CPR E 381	4	COM S 311 or CPR E 315	3
CPR E 310	3	CPR E 308	4
COM S 309	3	ENGL 314 or ENGL 309	3
E E 230	4	General Education Elective	3
CPR E 394	0	E E Elective	3
General Education Elective	3		
	17		16

Fourth Year

Fall	Credits	Spring	Credits
CPR E 491	3	CPR E 492	2
CPR E 494	0	Computer Science Elective	3
STAT 330	3	Technical Elective	3
Technical Electives	6	General Education Elective	3
CPR E Elective	3	CPR E Elective	3
General Education Elective	3		
	18		14

Graduate Study

The department offers work for the degrees Master of Engineering, Master of Science, and Doctor of Philosophy with a major in computer engineering and minor work to students with other majors. Minor work for computer engineering majors is usually selected from a wide range of courses outside computer engineering.

The Master of Engineering degree is course-work only. It is recommended for off-campus students.

The Master of Science degree with thesis is recommended for students who intend to continue toward the Doctor of Philosophy degree or to undertake a career in research and development. The non-thesis Master of Science degree requires a creative component.

The department also offers three graduate certificate programs in embedded systems, computer networking, and software systems.

The normal prerequisite to graduate major work in computer engineering is the completion of undergraduate work substantially equivalent to that required of computer engineering students at this university. It is possible for a student to qualify for graduate study in computer engineering even though the student's undergraduate or prior graduate training has been in a discipline other than computer engineering. Supporting work, if required, will depend on the student's background and area of research interest. Prospective students from a discipline other than computer engineering are required to submit, with the application for admission, a statement of the proposed area of graduate study.

The department requires submission of GRE General test scores by applicants. All students whose first language is not English and who have no U.S. degree must submit TOEFL examination scores. Students pursuing the Doctor of Philosophy must complete the department qualifying process.

The Department of Electrical and Computer Engineering is a participating department in the interdepartmental Master of Science and Doctor of Philosophy degree programs in bioinformatics and computational

biology. Students interested in these programs may earn their degrees while working under an adviser in electrical and computer engineering.

The Department of Electrical and Computer Engineering also is a participating department in the interdepartmental certificate, Master of Engineering, and Master of Science in Information Assurance programs. Students interested in studying information assurance topics may earn a degree in computer engineering or in information assurance. (See catalog section on Information Assurance.)

Well-qualified juniors and seniors in computer engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue both Bachelor of Science and Master of Science, or Bachelor of Science and Master of Business Administration, or Bachelor of Science and Master of Engineering degrees. Under concurrent enrollment, students are eligible for assistantships and simultaneously take undergraduate and graduate courses. Details are available in the Student Services Office and on the department's web site.

Courses primarily for undergraduates:

CPR E 131: Introduction to Computer Security Literacy
(Cross-listed with INFAS). (1-0) Cr. 1.
Basic concepts of practical computer and Internet security: passwords, firewalls, antivirus software, malware, social networking, surfing the Internet, phishing, and wireless networks. This class is intended for students with little or no background in information technology or security. Basic knowledge of word processing required. Offered on a satisfactory-fail basis only.

CPR E 166: Professional Programs Orientation
(Cross-listed with E E). Cr. R. F.S.
(1-0) Overview of the nature and scope of electrical engineering and computer engineering professions. Overview of portfolios. Departmental rules, student services operations, degree requirements, program of study planning, career options, and student organizations.

CPR E 185: Introduction to Computer Engineering and Problem Solving I
(2-2) Cr. 3.
Prereq: MATH 143 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165
Introduction to Computer Engineering. Project based examples from computer engineering. Individual interactive skills for small and large groups. Computer-based projects. Solving engineering problems and presenting solutions through technical reports. Solution of engineering problems using a programming language.

CPR E 186: Introduction to Computer Engineering and Problem Solving II
(0-2) Cr. 1. S.
Prereq: CPR E 185
Project based examples from computer engineering. Group skills needed to work effectively in teams. Group problem solving. Computer based projects. Technical reports and presentations. Students will work on 2 or 3 self-directed team based projects that are representative of problems faced by computer engineers.

CPR E 230: Cyber Security Fundamentals
(2-2) Cr. 3. F.
Prereq: COM S 107, COM S 207, COM S 227, or E E 285
Introduction to computer and network infrastructures used to support cyber security. Basic concepts of computer and network configuration used to secure environments. Computer virtualization, network routing and address translation, computer installation and configuration, network monitoring, in a virtual environment. Laboratory experiments and exercises including secure computer and network configuration and management.

CPR E 231: Cyber Security Concepts and Tools
(2-3) Cr. 3. S.
Prereq: CPR E 230
Basic concepts of practical computer and Internet security and the tools used to protect and attack systems and networks. Computer and network security methods including: user authentication, access control, firewalls, intrusion detection, use of vulnerability assessment tools and methods, and penetration testing. Ethics and legal issues in cyber security will also be covered. Laboratory experiments and exercises including evaluating systems for vulnerabilities, understanding potential exploits of the systems, and defenses for the systems.

CPR E 261: Transfer Orientation
(Cross-listed with E E). Cr. R.
Introduction to the College of Engineering and the engineering profession specifically for transfer students. Information concerning university and college policies, procedures, and resources. Offered on a satisfactory-fail basis only.

CPR E 281: Digital Logic
(3-3) Cr. 4. F.S.
Prereq: sophomore classification
Number systems and representation. Boolean algebra and logic minimization. Combinational and sequential logic design. Arithmetic circuits and finite state machines. Use of programmable logic devices. Introduction to computer-aided schematic capture systems, simulation tools, and hardware description languages. Design of simple digital systems.

CPR E 288: Embedded Systems I: Introduction
(3-2) Cr. 4. F.S.
Prereq: CPR E 281, COM S 207 or COM S 227 or E E 285
Embedded C programming. Interrupt handling. Memory mapped I/O in the context of an application. Elementary embedded design flow/ methodology. Timers, scheduling, resource allocation, optimization, state machine based controllers, real time constraints within the context of an application. Applications laboratory exercises with embedded devices.

CPR E 294: Program Discovery
(Cross-listed with E E). Cr. R.
Prereq: CPR E 166 or E E 166
The roles of professionals in computer and electrical engineering. Relationship of coursework to industry and academic careers. Issues relevant to today's world. Offered on a satisfactory-fail basis only.

CPR E 308: Operating Systems: Principles and Practice
(3-3) Cr. 4. F.S.
Prereq: CPR E 381 or COM S 321
Operating system concepts, processes, threads, synchronization between threads, process and thread scheduling, deadlocks, memory management, file systems, I/O systems,security, Linux-based lab experiments.

CPR E 310: Theoretical Foundations of Computer Engineering
(3-1) Cr. 3. F.S.
Prereq: COM S 228
Propositional logic and methods of proof; set theory and its applications; mathematical induction and recurrence relations; functions and relations; and counting; trees and graphs; applications in computer engineering.

CPR E 315: Applications of Algorithms in Computer Engineering
(3-0) Cr. 3. F.S.SS.
Prereq: CPR E 310
Solving computer engineering problems using algorithms. Emphasis on problems related to the core focus areas in computer engineering. Real world examples of algorithms used in the computer engineering domain. Algorithm engineering. Prototyping of algorithms.

CPR E 329: Software Project Management
(Cross-listed with S E). (3-0) Cr. 3.
Prereq: COM S 309
Process-based software development. Capability Maturity Model (CMM). Project planning, cost estimation, and scheduling. Project management tools. Factors influencing productivity and success. Productivity metrics. Analysis of options and risks. Version control and configuration management. Inspections and reviews. Managing the testing process. Software quality metrics. Modern software engineering techniques and practices.

CPR E 330: Integrated Electronics
(Cross-listed with E E). (3-3) Cr. 4.
Prereq: E E 201, credit or enrollment in E E 230, CPR E 281
Semiconductor technology for integrated circuits. Modeling of integrated devices including diodes, BJTs, and MOSFETs. Physical layout. Circuit simulation. Digital building blocks and digital circuit synthesis. Analysis and design of analog building blocks. Laboratory exercises and design projects with CAD tools and standard cells.

CPR E 332: Cyber Defense Competition
(Cross-listed with INFAS). (0-2) Cr. 1. Repeatable. S.
Participation in cyber defense competition driven by scenario-based network design. Includes computer system setup, risk assessment and implementation of security systems, as well as defense of computer and network systems against trained attackers. Team based. Offered on a satisfactory-fail basis only.

CPR E 339: Software Architecture and Design
(Cross-listed with S E). (3-0) Cr. 3.
Prereq: S E 319
Modeling and design of software at the architectural level. Architectural styles. Basics of model-driven architecture. Object-oriented design and analysis. Iterative development and unified process. Design patterns. Design by contract. Component based design. Product families. Measurement theory and appropriate use of metrics in design. Designing for qualities such as performance, safety, security, reliability, reusability, etc. Analysis and evaluation of software architectures. Introduction to architecture definition languages. Basics of software evolution, reengineering, and reverse engineering. Case studies. Introduction to distributed system software.

CPR E 370: Toying with Technology
(Cross-listed with MAT E). (2-2) Cr. 3. F.S.
Prereq: C I 201 or C I 202
A project-based, hands-on learning course. Technology literacy, appreciation for technological innovations, principles behind many technological innovations, hands-on laboratory experiences based upon simple systems constructed out of LEGOs and controlled by small microcomputers. Future K-12 teachers will leave the course with complete lesson plans for use in their upcoming careers.

CPR E 381: Computer Organization and Assembly Level Programming
(3-2) Cr. 4. F.S.
Prereq: CPR E 288
Introduction to computer organization, evaluating performance of computer systems, instruction set design. Assembly level programming: arithmetic operations, control flow instructions, procedure calls, stack management. Processor design. Datapath and control, scalar pipelines, introduction to memory and I/O systems.

CPR E 388: Embedded Systems II: Mobile Platforms
(3-2) Cr. 4.
Prereq: CPR E 288
Contemporary programming techniques for event driven systems. Mobile platforms and operating systems. Location and motion sensors based user interfaces. Threading and scheduling. Resource management - measurement and control techniques - for memory and energy. Client-server application design. Distributed applications. Laboratory includes exercises based on a mobile platform.

CPR E 394: Program Exploration
(Cross-listed with E E). Cr. R.
Prereq: CPR E 294 or E E 294
Exploration of academic and career fields for electrical and computer engineers. Examination of professionalism in the context of engineering and technology with competencies based skills. Introduction to professional portfolio development and construction. Offered on a satisfactory-fail basis only.

CPR E 396: Summer Internship
Cr. R. Repeatable. SS.
Prereq: Permission of department and Engineering Career Services
Professional work period of at least 10 weeks during the summer. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

CPR E 398: Cooperative Education (Co-op)
Cr. R. Repeatable. F.S.
Prereq: Permission of department and Engineering Career Services
Professional work period. One semester per academic or calendar year. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

CPR E 412: Formal Methods in Software Engineering
(Cross-listed with COM S, S E). (3-0) Cr. 3.
Prereq: COM S 230 or CPR E 310; COM S 311, STAT 330; for graduate credit: graduate standing or permission of instructor
A study of formal techniques for model-based specification and verification of software systems. Topics include logics, formalisms, graph theory, numerical computations, algorithms and tools for automatic analysis of systems. Graduate credit requires in-depth study of concepts.

CPR E 416: Software Evolution and Maintenance
(Cross-listed with S E). (3-0) Cr. 3.
Prereq: COM S 309
Practical importance of software evolution and maintenance, systematic defect analysis and debugging techniques, tracing and understanding large software, impact analysis, program migration and transformation, refactoring, tools for software evolution and maintenance, experimental studies and quantitative measurements of software evolution. Written reports and oral presentation.

CPR E 418: High Speed System Engineering Measurement and Testing
(Cross-listed with E E). (3-2) Cr. 4. F.
Prereq: E E 230 and E E 311
Measurement of high speed systems and mixed signal systems. Measurement accuracy and error. Network analysis and spectrum analysis used in high speed measurement and testing. Test specification process and parametric measurement. Sampling and digital signal processing concepts. Design for testability. Testing equipment. Applications.

CPR E 419: Software Tools for Large Scale Data Analysis
(Cross-listed with S E). (3-3) Cr. 4.
Prereq: CPR E 308 or COM S 352, COM S 309
Software tools for managing and manipulating large volumes of data, external memory processing, large scale parallelism, and stream processing, data interchange formats. Weekly programming labs that involve the use of a parallel computing cluster.

CPR E 424: Introduction to High Performance Computing
(Cross-listed with COM S, MATH). (2-2) Cr. 3. F.
Prereq: MATH 265; MATH 207 or MATH 317
UNIX, serial programming for high performance, OpenMP for high performance, shared memory parallelization. Semester project required.

CPR E 425: High Performance Computing for Scientific and Engineering Applications
(Cross-listed with COM S). (3-1) Cr. 3.
Prereq: COM S 311, COM S 230, ENGL 250, SP CM 212
Introduction to high performance computing platforms including parallel computers and workstation clusters. Discussion of parallel architectures, performance, programming models, and software development issues. Sample applications from science and engineering. Practical issues in high performance computing will be emphasized via a number of programming projects using a variety of programming models and case studies. Oral and written reports.

CPR E 426: Introduction to Parallel Algorithms and Programming
(Dual-listed with CPR E 526). (Cross-listed with COM S). (3-2) Cr. 4. F.
Prereq: CPR E 308 or COM S 321, CPR E 315 or COM S 311
Models of parallel computation, performance measures, basic parallel constructs and communication primitives, parallel programming using MPI, parallel algorithms for selected problems including sorting, matrix, tree and graph problems, fast Fourier transforms.

CPR E 430: Network Protocols and Security
(Dual-listed with CPR E 530). (Cross-listed with INFAS). (3-0) Cr. 3.
Prereq: CPR E 381 or equivalent
Detailed examination of networking standards, protocols, and their implementation. TCP/IP protocol suite, network application protocols. Network security issues, attack and mitigation techniques. Emphasis on laboratory experiments.

CPR E 431: Basics of Information System Security
(3-0) Cr. 3. S.
Prereq: credit or enrollment in CPR E 308 or COM S 352
Introduction to and application of basic mechanisms for protecting information systems from accidental and intentional threats. Basic cryptography use and practice. Computer security issues including authentication, access control, and malicious code. Network security mechanisms such as intrusion detection, firewalls, IPSEC, and related protocols. Ethics and legal issues in information security. Wireless security. Programming and system configuration assignments.

CPR E 435: Analog VLSI Circuit Design
(Cross-listed with E E). (3-3) Cr. 4. S.
Prereq: E E 324, E E 330, E E 332, and either E E 322 or STAT 330
Basic analog integrated circuit and system design including design space exploration, performance enhancement strategies, operational amplifiers, references, integrated filters, and data converters.

CPR E 444: Bioinformatic Analysis
(Cross-listed with BCB, BCBIO, BIOL, COM S, GEN). (4-0) Cr. 4. F.
Prereq: MATH 165 or STAT 401 or equivalent.
Broad overview of bioinformatics with a significant problem-solving component, including hands-on practice using computational tools to solve a variety of biological problems. Topics include: bioinformatic data processing, Perl programming, genome assembly, database search, sequence alignment, gene prediction, next-generation sequencing, comparative and functional genomics, and systems biology.

CPR E 450: Distributed Systems and Middleware
(Dual-listed with CPR E 550). (3-0) Cr. 3.
Prereq: CPR E 308 or COM S 352
Fundamentals of distributed computing, software agents, naming services, distributed transactions, security management, distributed object-based systems, web-based systems, middleware-based application design and development, case studies of middleware and internet applications.

CPR E 454: Distributed Systems
(Dual-listed with CPR E 554). (Cross-listed with COM S). (3-1) Cr. 3.
Prereq: COM S 311, COM S 352; for graduate credit: graduate standing or permission of instructor
Theoretical and practical issues of design and implementation of distributed systems. The client server paradigm, inter-process communications, synchronization and concurrency control, naming, consistency and replication, fault tolerance, and distributed file systems. Graduate credit requires additional in-depth study of concepts. Programming projects and written reports.

CPR E 458: Real Time Systems
(Dual-listed with CPR E 558). (3-0) Cr. 3.
Prereq: CPR E 308 or COM S 352
Fundamental concepts in real-time systems. Real time task scheduling paradigms. Resource management in uniprocessor, multiprocessor, and distributed real-time systems. Fault-tolerance, resource reclaiming, and overload handling. Real-time channel, packet scheduling, and real-time LAN protocols. Case study of real-time operating systems. Laboratory experiments.

CPR E 465: Digital VLSI Design
(Cross-listed with E E). (3-3) Cr. 4. F.
Prereq: E E 330
Digital design of integrated circuits employing very large scale integration (VLSI) methodologies. Technology considerations in design. High level hardware design languages, CMOS logic design styles, area-energy-delay design space characterization, datapath blocks: arithmetic and memory, architectures and systems on a chip (SOC) considerations. VLSI chip hardware design project.

CPR E 466: Multidisciplinary Engineering Design
(Cross-listed with A B E, AER E, B M E, E E, ENGR, I E, M E, MAT E). (1-4) Cr. 3. Repeatable. F.S.
Prereq: Student must be within two semesters of graduation; permission of instructor.
Application of team design concepts to projects of a multidisciplinary nature. Concurrent treatment of design, manufacturing, and life cycle considerations. Application of design tools such as CAD, CAM, and FEM. Design methodologies, project scheduling, cost estimating, quality control, manufacturing processes. Development of a prototype and appropriate documentation in the form of written reports, oral presentations and computer models and engineering drawings.

CPR E 467: Multidisciplinary Engineering Design II
(Cross-listed with AER E, E E, ENGR, I E, M E, MAT E). (1-4) Cr. 3. Repeatable, maximum of 2 times. Alt. F., offered irregularly.Alt. S., offered irregularly.
Prereq: Student must be within two semesters of graduation or receive permission of instructor.
Build and test of a conceptual design. Detail design, manufacturability, test criteria and procedures. Application of design tools such as CAD and CAM and manufacturing techniques such as rapid prototyping. Development and testing of a full-scale prototype with appropriate documentation in the form of design journals, written reports, oral presentations and computer models and engineering drawings.

CPR E 480: Graphics Processing and Architecture
(3-3) Cr. 4. S.
Prereq: CPR E 381 or COM S 321
Introduction to hardware architectures for computer graphics and their programming models. System-level view, including framebuffers, video output devices, displays, 2D and 3D graphics acceleration, and device interfacing. Architectural design of GPUs, from 2D and 3D sprite engines to 3D rendering pipelines to unified shader architectures. Computing models for graphics processors. GPGPU and GPU computing.

CPR E 483: Hardware Software Integration
(3-3) Cr. 4. S.
Prereq: CPR E 381
Embedded system design using hardware description language (HDL) and field programmable gate array (FPGA). HDL modeling concepts and styles are introduced; focus on synthesizability, optimality, reusability and portability in hardware design description. Introduction to complex hardware cores for data buffering, data input/output interfacing, data processing. System design with HDL cores and implementation in FPGA. Laboratory-oriented design projects.

CPR E 488: Embedded Systems Design
(3-3) Cr. 4.
Prereq: CPR E 381 or COM S 321
Embedded microprocessors, embedded memory and I/O devices, component interfaces, embedded software, program development, basic compiler techniques, platform-based FPGA technology, hardware synthesis, design methodology, real-time operating system concepts, performance analysis and optimizations.

CPR E 489: Computer Networking and Data Communications
(3-2) Cr. 4. F.S.
Prereq: CPR E 381 or E E 324
Modern computer networking and data communications concepts. TCP/IP, OSI protocols, client server programming, data link protocols, local area networks, and routing protocols.

CPR E 490: Independent Study
Cr. arr. Repeatable.
Prereq: Senior classification in computer engineering
Investigation of an approved topic.

CPR E 490H: Independent Study: Honors
Cr. arr. Repeatable.
Prereq: Senior classification in computer engineering
Investigation of an approved topic.

CPR E 491: Senior Design Project I and Professionalism
(Cross-listed with E E). (2-3) Cr. 3. F.S.
Prereq: E E 322 or CPR E 308, completion of 24 credits in the E E core professional program or 29 credits in the Cpr E core professional program, ENGL 314
Preparing for entry to the workplace. Selected professional topics. Use of technical writing skills in developing project plan and design report; design review presentation. First of two-semester team-oriented, project design and implementation experience.

CPR E 492: Senior Design Project II
(Cross-listed with E E). (1-3) Cr. 2. F.S.
Prereq: CPR E 491 or E E 491
Second semester of a team design project experience. Emphasis on the successful implementation and demonstration of the design completed in E E 491 or Cpr E 491 and the evaluation of project results. Technical writing of final project report; oral presentation of project achievements; project poster.

CPR E 494: Portfolio Assessment
(Cross-listed with E E). Cr. R.
Prereq: CPR E 394 or E E 394, credit or enrollment in CPR E 491 or E E 491
Portfolio update and evaluation. Portfolios as a tool to enhance career opportunities.

Courses primarily for graduate students, open to qualified undergraduates:

CPR E 501: Analog and Mixed-Signal VLSI Circuit Design Techniques
(Cross-listed with E E). (3-3) Cr. 4. F.
Prereq: E E 435
Design techniques for analog and mixed-signal VLSI circuits. Amplifiers; operational amplifiers, transconductance amplifiers, finite gain amplifiers and current amplifiers. Linear building blocks; differential amplifiers, current mirrors, references, cascading and buffering. Performance characterization of linear integrated circuits; offset, noise, sensitivity and stability. Layout considerations, simulation, yield and modeling for high-performance linear integrated circuits.

CPR E 504: Power Management for VLSI Systems
(Cross-listed with E E). (3-3) Cr. 4.
Prereq: E E 435, Credit or Registration for E E 501
Theory, design and applications of power management and regulation circuits (Linear and switching regulators, battery chargers, and reference circuits) including: Architectures, Performance metrics and characterization, Noise and stability analysis, Practical implementation and on-chip integration issues, design considerations for portable, wireless, and RF SoCs.

CPR E 505: CMOS and BiCMOS Data Conversion Circuits
(Cross-listed with E E). (3-3) Cr. 4. Alt. S., offered even-numbered years.
Prereq: E E 501
Theory, design and applications of data conversion circuits (A/D and D/A converters) including: architectures, characterization, quantization effects, conversion algorithms, spectral performance, element matching, design for yield, and practical comparators, implementation issues.

CPR E 506: Design of CMOS Phase-Locked Loops
(Cross-listed with E E). (3-3) Cr. 4.
Prereq: E E 435 or E E 501 or instructor approval
Analysis and design of phase-locked loops implemented in modern CMOS processes including: architectures, performance metrics, and characterization; noise and stability analysis; and design issues of phase-frequency detectors, charge pumps, loop filters (passive and active), voltage controlled oscillators, and frequency dividers.

CPR E 507: VLSI Communication Circuits
(Cross-listed with E E). (3-3) Cr. 4. Alt. S., offered odd-numbered years.
Prereq: E E 435 or E E 501
Phase-locked loops, frequency synthesizers, clock and data recovery circuits, theory and implementation of adaptive filters, low-noise amplifiers, mixers, power amplifiers, transmitter and receiver architectures.

CPR E 511: Advanced Design and Analysis of Algorithms
(Cross-listed with COM S). (3-0) Cr. 3.
Prereq: COM S 311
A study of algorithm design and analysis techniques. Advanced data structures, amortized analysis and randomized algorithms. Applications to sorting, graphs, and geometry. NP-completeness and approximation algorithms.

CPR E 522: Cognitive Radio Networks
(Cross-listed with E E). (3-0) Cr. 3. Alt. F., offered irregularly.
Prereq: Permission of instructor
Topics on cognitive radio networks: Cognitive Radio Networks Architecture; Software Defined Radio Architecture; Spectrum Sensing; Spectrum Management; Spectrum Sharing; Spectrum Mobility; Applications of Cognitive Radio Networks.

CPR E 525: Numerical Analysis of High Performance Computing
(Cross-listed with COM S, MATH). (3-0) Cr. 3. S.
Prereq: CPR E 308 or MATH 481; experience in scientific programming; knowledge of FORTRAN or C
Introduction to parallelization techniques and numerical methods for distributed memory high performance computers. A semester project in an area related to each student's research interests is required.

CPR E 526: Introduction to Parallel Algorithms and Programming
(Dual-listed with CPR E 426). (Cross-listed with COM S). (3-2) Cr. 4. F.
Prereq: CPR E 308 or COM S 321, CPR E 315 or COM S 311
Models of parallel computation, performance measures, basic parallel constructs and communication primitives, parallel programming using MPI, parallel algorithms for selected problems including sorting, matrix, tree and graph problems, fast Fourier transforms.

CPR E 528: Probabilistic Methods in Computer Engineering
(3-0) Cr. 3.
Prereq: CPR E 315 or COM S 311
The application of randomization and probabilistic methods in the design of computer algorithms, and their efficient implementation. Discrete random variables in modeling algorithm behavior, with applications to sorting, selection, graph algorithms, hashing, pattern matching, cryptography, distributed systems, and massive data set algorithmics.

CPR E 529: Data Analytics in Electrical and Computer Engineering
(Cross-listed with E E). (3-0) Cr. 3. S.
Prereq: E E 322 or equivalent
Introduces a variety of data analytics techniques # particularly those relevant for electrical and computer engineers # from a foundational perspective. Topics to be covered include techniques for classification, visualization, and parameter estimation, with applications to signals, images, matrices, and graphs. Emphasis will be placed on rigorous analysis as well as principled design of such techniques.

CPR E 530: Network Protocols and Security
(Dual-listed with CPR E 430). (Cross-listed with INFAS). (3-0) Cr. 3.
Prereq: CPR E 381 or equivalent
Detailed examination of networking standards, protocols, and their implementation. TCP/IP protocol suite, network application protocols. Network security issues, attack and mitigation techniques. Emphasis on laboratory experiments.

CPR E 531: Information System Security
(Cross-listed with INFAS). (3-0) Cr. 3.
Prereq: CPR E 489 or CPR E 530 or COM S 586 or MIS 535
Computer, software, and data security: basic cryptography, security policies, multilevel security models, attack and protection mechanisms, legal and ethical issues.

CPR E 532: Information Warfare
(Cross-listed with INFAS). (3-0) Cr. 3. S.
Prereq: CPR E 531
Computer system and network security: implementation, configuration, testing of security software and hardware, network monitoring. Authentication, firewalls, vulnerabilities, exploits, countermeasures. Study and use of attack tools. Ethics in information assurance. Emphasis on laboratory experiments.

CPR E 533: Cryptography
(Cross-listed with INFAS, MATH). (3-0) Cr. 3. S.
Prereq: MATH 301 or CPR E 310 or COM S 330
Basic concepts of secure communication, DES and AES, public-key cryptosystems, elliptic curves, hash algorithms, digital signatures, applications. Relevant material on number theory and finite fields.

CPR E 534: Legal and Ethical Issues in Information Assurance
(Cross-listed with INFAS, POL S). (3-0) Cr. 3. S.
Prereq: Graduate classification; CPR E 531 or INFAS 531
Legal and ethical issues in computer security. State and local codes and regulations. Privacy issues.

CPR E 535: Steganography and Digital Image Forensics
(Cross-listed with INFAS, MATH). (3-0) Cr. 3. S.
Prereq: E E 524 or MATH 317 or MATH 407 or COM S 330
Basic principles of covert communication, steganalysis, and forensic analysis for digital images. Steganographic security and capacity, matrix embedding, blind attacks, image forensic detection and device identification techniques. Related material on coding theory, statistics, image processing, pattern recognition.

CPR E 536: Computer and Network Forensics
(Cross-listed with INFAS). (3-0) Cr. 3.
Prereq: CPR E 489 or CPR E 530
Fundamentals of computer and network forensics, forensic duplication and analysis, network surveillance, intrusion detection and response, incident response, anonymity and pseudonymity, privacy-protection techniques, cyber law, computer security policies and guidelines, court testimony and report writing, and case studies. Emphasis on hands-on experiments.

CPR E 537: Wireless Network Security
(3-0) Cr. 3. S.
Prereq: Credit or enrollment in CPR E 489 or CPR E 530
Introduction to the physical layer and special issues associated with the security of wireless networks. The basics of wireless communication systems (antennas and propagation, modulation, multiple access, channel modeling, specific security issues of the wireless link), jamming and countermeasures (spread spectrum technologies, channel coding, interleaving), authentication and confidentiality (basics of classic cryptography, common authentication and encryption algorithms). Detailed case studies on authentication, encryption and privacy flaws, and good practices based on the most common wireless technologies, including WiFi, GSM/3G, Bluetooth, and RFID. Individual or team-based class projects.

CPR E 538: Reverse Engineering and Security Testing
(Cross-listed with INFAS). (2-3) Cr. 3. S.
Prereq: COM S 321 or CPR E 381, COM S 352 or CPR E 308
Techniques and tools for understanding the behavior of software/hardware systems based on reverse engineering. Flaw hypothesis, black, grey, and white box testing as well as other methods for testing the security of software systems. Discussion of counter-reverse engineering techniques.

CPR E 539: Cyber Physical System Security for the Smart Grid
(3-0) Cr. 3. S.
Introduction to cyber security, cyber physical system (CPS), and smart grid automation technologies; supervisor control and data acquisition (SCADA) systems; cyber risk modeling, vulnerability analysis, impact analysis, defense and mitigation techniques; cyber security of wide-area monitoring, protection, and control; security and privacy in advanced metering infrastructure (AMI), cyber security compliance and best practices, CPS security test-beds and attack-defense hands-on laboratory experiments.

CPR E 541: High-Performance Communication Networks
(3-0) Cr. 3.
Prereq: CPR E 489 or CPR E 530
Computer architectures and protocols designed for high-performance networking environments; software defined networking (SDN) and supporting protocols; cloud and data center networks; network traffic management and congestion control strategies; quality of service; high-speed access network protocols.

CPR E 542: Optical Communication Networks
(3-0) Cr. 3. S.
Prereq: CPR E 489
Optical components and interfaces; optical transmission and reception techniques; wavelength division multiplexing; network architectures and protocol for first generation, single and multihop optical network; routing and wavelength assignment in second generation wavelength routing networks; traffic grooming, optical network control; survivability; access networks; metro networks.

CPR E 543: Wireless Network Architecture
(3-0) Cr. 3.
Prereq: Credit or enrollment in CPR E 489 or CPR E 530
Introduction to the protocol architecture of the data link layer, network layer and transport layer for wireless networking. Operation and management of Medium Access Control in Wireless Local Area Networks (WLAN) and Wireless Metropolitan Area Networks (WMAN); recent developments in IEEE 802.11 & 802.16 and Bluetooth; Mobile IP; Mobile TCP.

CPR E 544: Fundamentals of Bioinformatics
(Cross-listed with BCB, COM S, GDCB). (4-0) Cr. 4. F.
Prereq: MATH 165 or STAT 401 or equivalent
A practical, hands-on overview of how to apply bioinformatics to biological research. Recommended for biologists desiring to gain computational molecular biology skills. Topics include: sequence analysis, genomics, proteomics, phylogenetic analyses, ontology enrichment, systems biology, data visualization and emergent technologies.

CPR E 545: Fault-Tolerant Systems
(3-0) Cr. 3.
Prereq: CPR E 381
Faults and their manifestations, errors, and failures; fault detection, location and reconfiguration techniques; time, space, and information (coding) redundancy management; design for testability; self-checking and fail-safe circuits; system-level fault diagnosis; Byzantine agreement; stable storage and RAID; clock synchronization; fault-tolerant networks; fault tolerance in real-time systems; reliable software design; checkpointing and rollback recovery; atomic actions; replica management protocols; and reliability evaluation techniques and tools.

CPR E 546: Wireless and Sensor Networks
(3-0) Cr. 3.
Prereq: CPR E 489 or CPR E 530
Fundamental and well-known protocols for wireless ad hoc and sensor networks at various layers, including physical layer issues, MAC (medium access control) layer protocols, routing protocols for wireless ad hoc and sensor networks, data management in sensor networks, coverage and connectivity, localization and tracking, security and privacy issues. Introduction to TinyOS and the nesC language. Hands-on experiments with Crossbow Mote sensor devices.

CPR E 547: Resource Allocation in Communication Networks
(3-0) Cr. 3.
Analytical approach to resource allocation on communication networks (e.g. the Internet, multihop wireless networks, etc.). Network utility maximization and the internet congestion control algorithm. Layering as optimization decomposition: a cross-layer design approach in multihop wireless networks. Capacity of ad hoc wireless networks.

CPR E 549: Advanced Algorithms in Computational Biology
(Cross-listed with COM S). (3-0) Cr. 3.
Prereq: COM S 311 and either COM S 228 or COM S 208
Design and analysis of algorithms for applications in computational biology, pairwise and multiple sequence alignments, approximation algorithms, string algorithms including in-depth coverage of suffix trees, semi-numerical string algorithms, algorithms for selected problems in fragment assembly, phylogenetic trees and protein folding. No background in biology is assumed. Also useful as an advanced algorithms course in string processing.

CPR E 550: Distributed Systems and Middleware
(Dual-listed with CPR E 450). (3-0) Cr. 3.
Prereq: CPR E 308 or COM S 352
Fundamentals of distributed computing, software agents, naming services, distributed transactions, security management, distributed object-based systems, web-based systems, middleware-based application design and development, case studies of middleware and internet applications.

CPR E 554: Distributed Systems
(Dual-listed with CPR E 454). (Cross-listed with COM S). (3-1) Cr. 3.
Prereq: COM S 311, COM S 352; for graduate credit: graduate standing or permission of instructor
Theoretical and practical issues of design and implementation of distributed systems. The client server paradigm, inter-process communications, synchronization and concurrency control, naming, consistency and replication, fault tolerance, and distributed file systems. Graduate credit requires additional in-depth study of concepts. Programming projects and written reports.

CPR E 556: Scalable Software Engineering
(3-0) Cr. 3.
Prereq: COM S 309
Design and analysis techniques scalable to large software, project-based learning of problem solving techniques, automation tools for high productivity and reliability of software, analysis-based measurement and estimation techniques for predictable software engineering.

CPR E 557: Computer Graphics and Geometric Modeling
(Cross-listed with COM S, M E). (3-0) Cr. 3. F.
Prereq: M E 421, programming experience in C
Fundamentals of computer graphics technology. Data structures. Parametric curve and surface modeling. Solid model representations. Applications in engineering design, analysis, and manufacturing.

CPR E 558: Real Time Systems
(Dual-listed with CPR E 458). (3-0) Cr. 3.
Prereq: CPR E 308 or COM S 352
Fundamental concepts in real-time systems. Real time task scheduling paradigms. Resource management in uniprocessor, multiprocessor, and distributed real-time systems. Fault-tolerance, resource reclaiming, and overload handling. Real-time channel, packet scheduling, and real-time LAN protocols. Case study of real-time operating systems. Laboratory experiments.

CPR E 566: Physical Design of VLSI Systems
(3-0) Cr. 3.
Prereq: CPR E 465
Physical design of VLSI systems. Partitioning algorithms. Placement and floorplanning algorithms. Routing-global and detailed. Layout compaction. Physical design of FPGA's and MCM's. Performance-driven layout synthesis.

CPR E 567: Bioinformatics I (Bioinformatics Algorithms)
(Cross-listed with BCB, COM S). (3-0) Cr. 3.
Prereq: COM S 228; COM S 330; credit or enrollment in BIOL 315, STAT 430
Biology as an information science. A review of the algorithmic principles that are driving the advances in bioinformatics and computational biology.

CPR E 569: Bioinformatics III (Structural Bioinformatics)
(Cross-listed with BBMB, BCB, COM S, GDCB). (3-0) Cr. 3. F.
Prereq: BCB 567, BBMB 316, GEN 409, STAT 430
Molecular structures including genes and gene products: protein, DNA and RNA structure. Structure determination methods, structural refinement, structure representation, comparison of structures, visualization, and modeling. Molecular and cellular structure from imaging. Analysis and prediction of protein secondary, tertiary, and higher order structure, disorder, protein-protein and protein-nucleic acid interactions, protein localization and function, bridging between molecular and cellular structures. Molecular evolution.

CPR E 570: Bioinformatics IV (Systems Biology)
(Cross-listed with BCB, COM S, GDCB, STAT). (3-0) Cr. 3. S.
Prereq: BCB 567 or COM S 311, COM S 228, GEN 409, STAT 430
Algorithmic and statistical approaches in computational functional genomics and systems biology. Analysis of high throughput biological data obtained using system-wide measurements. Topological analysis, module discovery, and comparative analysis of gene and protein networks. Modeling, analysis, and inference of transcriptional regulatory networks, protein-protein interaction networks, and metabolic networks. Dynamic systems and whole-cell models. Ontology-driven, network based, and probabilistic approaches to information integration.

CPR E 575: Computational Perception
(Cross-listed with COM S, HCI). (3-0) Cr. 3. S.
Prereq: Graduate standing or permission of instructor
Statistical and algorithmic methods for sensing, recognizing, and interpreting the activities of people by a computer. Focuses on machine perception techniques that facilitate and augment human-computer interaction. Introduce computational perception on both theoretical and practical levels. Participation in small groups to design, implement, and evaluate a prototype of a human-computer interaction system that uses one or more of the techniques covered in the lectures.

CPR E 581: Computer Systems Architecture
(Cross-listed with COM S). (3-0) Cr. 3. F.
Prereq: CPR E 381
Quantitative principles of computer architecture design, instruction set design, processor architecture: pipelining and superscalar design, instruction level parallelism, memory organization: cache and virtual memory systems, multiprocessor architecture, cache coherency, interconnection networks and message routing, I/O devices and peripherals.

CPR E 582: Computer Systems Performance
(3-0) Cr. 3.
Prereq: CPR E 381, CPR E 310 and STAT 330
Review of probability and stochastic processes concepts; Markovian processes; Markovian queues; renewal theory; semi-Markovian queues; queueing networks, applications to multiprocessor architectures, computer networks, and switching systems.

CPR E 583: Reconfigurable Computing Systems
(Cross-listed with COM S). (3-0) Cr. 3.
Prereq: Background in computer architecture, design, and organization
Introduction to reconfigurable computing, FPGA technology and architectures, spatial computing architectures such as systolic and bit serial adaptive network architectures, static and dynamic rearrangeable interconnection architectures, processor architectures incorporating reconfigurabiltiy.

CPR E 584: Models and Techniques in Embedded Systems
(3-0) Cr. 3.
Industry-standard tools and optimization strategies; practical embedded platforms and technology (reconfigurable platforms, multi-core platforms, low-power platforms); instruction augmentation, memory-mapped accelerator design, embedded software optimization. Students will be encouraged to compete as teams in an embedded system design competition.

CPR E 585: Developmental Robotics
(Cross-listed with HCI). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: knowledge of C/C++ programming language.
An introduction to the emerging interdisciplinary field of Developmental Robotics, which crosses the boundaries between robotics, artificial intelligence, developmental psychology, and philosophy. The main goal of this field is to create autonomous robots that are more intelligent, more adaptable, and more useful than the robots of today, which can only function in very limited domains and situations.

CPR E 586: Pervasive Computing
(3-0) Cr. 3.
Prereq: CPR E 489 or CPR E 530
Fundamentals of pervasive computing, including location and context awareness, mobile and location services, ubiquitous data access, low power computing and energy management, middleware, security and privacy issues.

CPR E 588: Embedded Computer Systems
(3-0) Cr. 3.
Prereq: CPR E 308
Hardware/software systems and codesign. Models of computation for embedded systems. System-level design. Modeling, specification, synthesis, and verification. Hardware/software implementation. Design space exploration. Performance analysis and optimization. Multiprocessor system on chip. Platform-based design. Design methodologies and tools. Case studies and design projects.

CPR E 590: Special Topics
Cr. 1-6. Repeatable.
Formulation and solution of theoretical or practical problems in computer engineering.

CPR E 592: Seminar in Computer Engineering
Cr. 1-4. Repeatable.
Prereq: Permission of instructor
Projects or seminar in Computer Engineering.

CPR E 594: Selected Topics in Computer Engineering
(3-0) Cr. 3. Repeatable.

CPR E 599: Creative Component
Cr. arr. Repeatable.

Courses for graduate students:

CPR E 626: Parallel Algorithms for Scientific Applications
(Cross-listed with COM S). (3-0) Cr. 3.
Prereq: CPR E 526
Algorithm design for high-performance computing. Parallel algorithms for multidimensional tree data structures, space-filling curves, random number generation, graph partitioning and load balancing. Applications to grid and particle-based methods and computational biology.

CPR E 632: Information Assurance Capstone Design
(Cross-listed with INFAS). (3-0) Cr. 3.
Prereq: INFAS 531, INFAS 532, INFAS 534
Capstone design course which integrates the security design process. Design of a security policy. Creation of a security plan. Implementation of the security plan. The students will attack each other's secure environments in an effort to defeat the security systems. Students evaluate the security plans and the performance of the plans. Social, political and ethics issues. Student self-evaluation, journaling, final written report.

CPR E 681: Advanced Topics in Computer Architecture
(Cross-listed with COM S). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: CPR E 581. Repeatable with Instructor permission
Current topics in computer architecture design and implementation. Advanced pipelining, cache and memory design techniques. Interaction of algorithms with architecture models and implementations. Tradeoffs in architecture models and implementations.

CPR E 697: Engineering Internship
(Cross-listed with E E). Cr. R. Repeatable.
One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

CPR E 699: Research
Cr. arr. Repeatable.