DEPARTMENT OF COMPUTER SCIENCE

Mission Statement

The core mission is to provide an inclusive learning environment and conduct ethical and excellence-driven teaching and research in computer science to benefit departmental stakeholders including students, faculty, the university, the local community, and the society at large. To fulfill this mission, the Department will:

- Use innovative and experiential learning models and research to prepare students for careers in industry, government, and academia.
- Develop leadership in the education of underrepresented and disadvantaged groups.
- Enhance the nationally prominent research, education, outreach programs in cybersecurity, develop the cross-cutting research thrusts of data-driven intelligence and virtual reality systems, and networked and software systems

General Information

The Department of Computer Science is engaged in cutting-edge research in cross-cutting research thrust areas of Cybersecurity, Data-driven Intelligence and Virtual Reality Systems, and Networked and Software Systems, with expertise in Artificial Intelligence; Machine Learning; Big Data; Software Engineering; Cloud Computing; Cybersecurity; Bioinformatics; Internet-of-Things; Embedded Systems; Parallel, Distributed, and High-performance Computing; and Computer Graphics and Virtual and Augmented Reality. The Department of Computer Science operates dedicated classrooms, a large instructional lab, 20 research labs, and two main research units, the Center for Infrastructure Assurance and Security (CIAS) and the Institute for Cyber Security (ICS). Its faculty members are also affiliated with UT San Antonio's School of Data Science, National Security Collaboration Center, and AI Matrix Consortium.

The Department of Computer Science offers excellent learning and research opportunities to graduate students. Students engaged in research will be able to work with state-of-the-art computing clusters and research equipment operated by the Department of Computer Science and UT San Antonio, including a 113-compute node cluster, as well as AI workstations with cutting-edge GPUs.

Degrees

The Department of Computer Science offers a Master of Science degree in Computer Science, a Master of Science degree in Cybersecurity Science, a Master of Science degree in Artificial Intelligence (through the College of AI, Cyber and Computing), a Doctor of Philosophy degree in Computer Science, and a Graduate Certificate in Cloud Computing.

Degree-Specific Requirements

All program requirements should be unchanged from previous versions of the 2025-2027 Graduate Catalog. To confirm your degree requirements, you can visit DegreeWorks (https://dworkswebprod.sis.utsa.edu/) or consult your Graduate Advisor of Record.

Master of Science Degree in Artificial Intelligence

UT San Antonio offers a graduate-studies program leading to the Master of Science degree in Artificial Intelligence. This program is administered by the College of AI, Cyber and Computer. Please refer to the College of AI, Cyber and Computer (https://catalog.utsa.edu/graduate/aicybercomputing/) section of this catalog for details about this program.

Master of Science Degree in Computer Science

The Master of Science (M.S.) degree in Computer Science offers integrated studies involving software and hardware. A Thesis Option is available for students who wish to obtain research experience. The Department of Computer Science also offers Concentrations in Cybersecurity, Software Engineering, and Data Science as part of the Master of Science degree.

The regulations for this degree comply with the general University regulations (refer to Student Policies, General Academic Regulations, and Graduate Catalog, Master's Degree Regulations).

Admission Requirements

The minimum requirements for admission to the Master of Science degree program in Computer Science, in addition to University-wide graduate admission requirements, are as follows:

- A B.A. or B.S. degree in computer science equivalent to that offered by UT San Antonio
- Two letters of recommendation attesting to the applicant's readiness for graduate study
- Professional résumé or curriculum vitae
- Statement of purpose

Satisfying the minimum requirements does not guarantee admission. Students who do not qualify for unconditional admission may be admitted on a conditional basis. Students who are admitted on a conditional basis may be required to complete specific undergraduate courses as conditions of admission. If such courses are listed as deficiencies, they will not count toward the graduate degree. In such cases, students should anticipate that additional time will be required to complete the degree.

Degree Requirements

Candidates for the degree are required to successfully complete a minimum of 30 semester credit hours of graduate coursework as described in the program of study.

Program of Study

Code	Title	Credit Hours
A. Core courses:		6
CS 5523	Operating Systems	
CS 5633	Analysis of Algorithms	
B. Required CS fundamental electives		3
Select one of the following courses:		

CS 5513	Computer Architecture	
CS 5363	Programming Languages and Compilers	
C. Other Electives:		15
Students must complete at least 15 semester credit hours of additional eligible graduate courses. With prior approval of the Graduate Advisor of Record, students may apply a maximum of 6 hours of graduate courses from other disciplines to the degree.		
D. Master's thesis or additional electives:		6
Students must either write a master's thesis and enroll in a minimum of 6 semester credit hours of CS 5971, CS 5972, CS 5973, Directed Research, CS 6953 Independent Study, or CS 6981 or CS 6983 Master's Thesis (including a minimum of 3 semester credit hours of CS 6981 or CS 6983 Master's Thesis), or complete 6 hours of additional graduate coursework in the Department of Computer Science.		
Total Credit Hours		**30**

Concentration in Cybersecurity

This concentration gives an overview of issues in computer and information security along with detailed technical experience in several specialty areas. All students pursuing this concentration must fulfill the degree requirements for the Master of Science in Computer Science. As part of the electives for the degree, students must take the following courses:

Code	Title	Credit Hours
CS 5323	Principles of Cybersecurity	3
Select two of the following courses, or other course(s) approved by the Graduate Studies Committee:		6
CS 5343	Developing Secure Systems and Software	
CS 5713	Practical Attack and Defense Techniques	
CS 6323	Cybersecurity Models and Systems	
CS 6353	Network and System Security	
CS 6373	Applied Cryptography	
CS 6393	Advanced Topics in Computer Security	
Total Credit Hours		**9**

Concentration in Software Engineering

This concentration gives students a broad knowledge of current theories, models, and techniques in software engineering to provide a basis for problem identification and analysis, software design, development, implementation, verification, and documentation. All students pursuing this concentration must fulfill the degree requirements for the Master of Science in Computer Science. As part of the electives for the degree, students must take the following courses:

Code	Title	Credit Hours
CS 5103	Software Engineering	3
Select two of the following courses, or other course(s) approved by the Graduate Studies Committee:		6
CS 5123	Software Testing and Quality Assurance	
CS 5153	User Interfaces and Usability	
CS 5343	Developing Secure Systems and Software	
CS 6133	Software Specification and Verification	
Total Credit Hours		**9**

Concentration in Data Science

This concentration provides students with the fundamental knowledge in data management, machine learning, data mining, statistics, data visualization, and communicating data. Students will have opportunities to specialize in applications such as health and life sciences, as well as to learn critical, generalizable skills. All students pursuing this concentration must fulfill the degree requirements for the Master of Science in Computer Science. As part of the electives for the degree, students must take the following courses:

Code	Title	Credit Hours
CS 5163	Data Science	3
Select two of the following courses (must include at least one of the courses marked with an *), or other course(s) approved by the Graduate Studies Committee:		6
CS 5443	Database Management Systems *	
CS 5493	Large-Scale Data Management *	
CS 5473	Data Mining *	
CS 5483	Topics in Data Science	
CS 5263	Bioinformatics	
CS 6243	Machine Learning	
Total Credit Hours		**9**

Master of Science Degree in Cybersecurity Science

The Master of Science (M.S.) degree in Cybersecurity Science offers a comprehensive and hands-on education in the area of Cybersecurity. The program provides students with a broad exposure to the highly dynamic Cybersecurity discipline, along with a deep technical and scientific understanding of the related concepts, tools, and techniques.

The regulations for this degree comply with the general University regulations (refer to Student Policies, General Academic Regulations, and Graduate Catalog, Master's Degree Regulations).

Admission Requirements

In addition to satisfying the University-wide graduate admission requirements, a bachelor's degree in computer science or related majors is required. The following documents are required:

- Statement of purpose
- Professional résumé or curriculum vitae
- Two letters of recommendation attesting to the applicant's readiness for graduate study

Students who do not qualify for unconditional admission may be admitted on a conditional basis. Students who are admitted on a conditional basis may be required to complete specific undergraduate (or bridge) courses as conditions offer admission. If such courses are listed as deficiencies, they will not count toward the graduate degree. In such cases, students should anticipate that additional time will be required to complete the degree.

Degree Requirements

Candidates for the degree are required to successfully complete a minimum of 30 semester credit hours of graduate coursework as described in the program of study below.

Program of Study

Code	Title	Credit Hours
A. Core courses:		6
CS 5323	Principles of Cyber Security	
CS 5713	Practical Attack and Defense Techniques	
B. Required Computer Science courses		6
Students must complete at least 6 credit hours of Computer Science graduate courses from the list below, or other course(s) approved by the Graduate Studies Committee.		
CS 5233	Artificial Intelligence	
CS 5363	Programming Languages and Compilers	
CS 5443	Database Management Systems	
CS 5513	Computer Architecture	
CS 5523	Operating Systems	
CS 5573	Cloud Computing	
CS 5633	Analysis of Algorithms	
CS 6243	Machine Learning	
CS 6543	Networks	
C. Required Electives on Cybersecurity Courses:		6
Students must complete 6 credit hours from the elective courses listed below.		
CS 5343	Developing Secure Systems and Software	
CS 6323	Cybersecurity Models and Systems	
CS 6353	Network and System Security	
CS 6373	Applied Cryptography	
D. Other Electives on Cybersecurity Courses:		6
Students must complete at least 6 credit hours from the elective courses listed below (the topics of CS 5463 and CS 6463 need to be cybersecurity related), or other course(s) related to cybersecurity and approved by the Graduate Studies Committee.		
CS 5453	Penetration Testing	
CS 5463	Topics in Computer Science	
CS 5723	Crypto Currencies and Bitcoins	
CS 5733	Privacy Enhancing Techniques	
CS 5933	Internship in Computer Science	
CS 6333	Cybersecurity Data Analytics	
CS 6343	Cyber Risk Management	
CS 6463	Advanced Topics in Computer Science	
IS 6363	Digital Forensics	
E. Master's thesis or additional electives:		6
Students must either write a master's thesis and enroll in a minimum of 6 semester credit hours of CS 5971, CS 5972, CS 5973 Directed Research, CS 6953 Independent Study, or CS 6981 or CS 6983 Master's Thesis (including a minimum of 3 semester credit hours of CS 6981 or CS 6983 Master's Thesis), or complete 6 hours of additional graduate coursework from the courses listed in D.		
Total Credit Hours		**30**

Doctor of Philosophy Degree in Computer Science

The Department of Computer Science offers advanced coursework and research leading to the Doctor of Philosophy (Ph.D.) degree in Computer Science. Successful Ph.D. candidates must demonstrate an in-depth knowledge of computer science and must deliver an original contribution to the field.

The regulations for this degree comply with the general University regulations (refer to Student Policies, General Academic Regulations, and the Graduate Catalog, Doctoral Degree Regulations).

Admission Requirements

The minimum requirements for admission to the Ph.D. program in Computer Science, in addition to University-wide graduate admission requirements, are as follows:

- A B.A., B.S., or M.S. degree in computer science or a related area.
- Three letters of recommendation attesting to the applicant's readiness for doctoral study.
- Professional résumé or curriculum vitae.
- Statement of research experience and interest.

Admission is competitive. Satisfying the minimum requirements does not guarantee admission. Applicants will automatically be considered for scholarships and teaching and research assistantships.

Degree Requirements

Candidates for the degree are required to successfully complete a minimum of 72 semester credit hours of graduate coursework as described in the program of study.

Program of Study

Code	Title	Credit Hours
A. Required Core course:		**3**
CS 5633	Analysis of Algorithms	
B. Elective Core courses		**9**
Students much complete at least 9 semester credit hours of elective core courses from the list below:		
CS 5103	Software Engineering	
CS 5163	Data Science	
CS 5233	Artificial Intelligence	
CS 5323	Principles of Cyber Security	
CS 5363	Programming Languages and Compilers	
CS 5513	Computer Architecture	
CS 5523	Operating Systems	
C. Elective courses		**12**
Students must complete at least 12 semester credit hours of additional eligible, organized graduate courses in the Department of Computer Science.		
D. Other Requirements:		**48**
Students must complete at least 48 semester credit hours of additional courses, including:		
A minimum of 3 semester credit hours of the following:		
CS 7123	Research Methods	
A minimum of 18 semester credit hours of the following:		

CS 7211	Doctoral Research	
CS 7212	Doctoral Research	
CS 7213	Doctoral Research	
CS 7216	Doctoral Research	
A minimum of 9 semester credit hours of the following:		
CS 7311	Doctoral Dissertation	
CS 7312	Doctoral Dissertation	
CS 7313	Doctoral Dissertation	
CS 7316	Doctoral Dissertation	
With prior approval of the Graduate Advisor of Record, students may apply a maximum of 6 hours of graduate courses from other disciplines to the degree.		
Total Credit Hours		**72**

Transfer of Credit

Students may transfer prior graduate study up to 30 semester credit hours from another institution toward the Doctor of Philosophy degree in Computer Science with the approval of the Graduate Studies Committee. Each student's transcript will be evaluated by the Graduate Studies Committee, and credit will be determined on a course-by-course basis to satisfy the requirements of the degree.

Admission to Candidacy

Students seeking a doctoral degree must be admitted to candidacy. The requirements for admission to candidacy are as follows:

- Achieve a grade point average of 3.3 or better in CS 5633 Analysis of Algorithms, and three elective core courses (from Section B).
- Pass the oral qualifying examination, which focuses on written and oral research capability requirements. Students should consult the Computer Science Ph.D. Program Handbook for additional details.
- Pass the Doctoral Dissertation Proposal Examination.

Students should consult the University's Doctoral Degree Regulations in the Graduate Catalog for other requirements.

Doctoral Dissertation Proposal Examination

The Doctoral Dissertation Proposal Examination is an oral examination administered and evaluated by the student's Dissertation Committee and covers the dissertation research proposal. The student must submit a written proposal prior to the examination. The Doctoral Dissertation Proposal Examination consists of a formal presentation of the dissertation proposal followed by an oral examination. Unanimous approval of the Dissertation Committee is required to pass the examination.

Doctoral Dissertation and Final Oral Examination

Students seeking a doctoral degree must submit a Doctoral Dissertation and pass a Final Oral Examination. The Final Oral Examination is administered and evaluated by the student's Dissertation Committee and covers the dissertation and the general field of the dissertation. The Final Oral Examination consists of an open presentation of the dissertation followed by an oral examination. Unanimous approval of the Dissertation Committee is required to pass the Final Oral Examination. Also, the Doctoral Dissertation must be unanimously approved by the Dissertation Committee.

Graduate Certificate in Cloud Computing

The Graduate Certificate in Cloud Computing is a 12-semester-credit-hour program designed to equip technical professionals with the knowledge and technical skills necessary for a career in an organization that leverages cloud computing. The wide range of use of cloud computing in today's business, government, and academic environments requires a broad range of competencies and understanding of how cloud computing influences a particular area. This certificate is designed to give a common framework of understanding cloud computing, as well as allow for specialization in specific areas, such as cyber-security, cloud-infrastructure, and applications in cloud. Students may take elective courses not listed with program approval.

The certificate is administered by the Klesse College of Engineering and Integrated Design in conjunction with the College of AI, Cyber and Computing. The course requirements for each program focus may be found under the Department of Electrical Engineering (https://catalog.utsa.edu/graduate/engineeringintegrateddesign/electricalengineering/), the Department of Computer Science, (p. 1) and the Department of Information Systems and Cybersecurity (https://catalog.utsa.edu/graduate/aicybercomputing/informationsystemscybersecurity/).

Certificate Program Requirements

To satisfy the requirements for the Graduate Certificate in Cloud Computing, students must complete 12 semester credit hours as follows:

Code	Title	Credit Hours
A. Required Course		**3**
Select one entry course:		
CS 5573	Cloud Computing	
Or a cross-listed course in EE and IS. The entry course is taught through team teaching in which an instructor from each college contributes to the subjects outlined in the course syllabus.		
B. Track Electives		**6**
Select two courses from one of the following tracks:		
Applications Track		
CS 5233	Artificial Intelligence	
CS 5263	Bioinformatics	
CS 5443	Database Management Systems	
CS 5463	Topics in Computer Science	
CS 5473	Data Mining	
CS 5493	Large-Scale Data Management	
CS 6243	Machine Learning	
Security Track		
CS 5323	Principles of Cyber Security	
CS 6323	Cybersecurity Models and Systems	
CS 6353	Network and System Security	
CS 6373	Applied Cryptography	
CS 6393	Advanced Topics in Computer Security	
IS 6363	Digital Forensics	
Infrastructure Track		
CS 5103	Software Engineering	
CS 5123	Software Testing and Quality Assurance	
CS 6463	Advanced Topics in Computer Science	

CS 6463	Advanced Topics in Computer Science (Topic: Parallel and Distribute Systems Software)	
CS 6543	Networks	
CS 6553	Performance Evaluation	
CS 6643	Parallel Processing	
C. Capstone Project		**3**
Select one course from the following (topics should be in the field of Cloud Computing):		
CS 5973	Directed Research	
CS 6953	Independent Study	
Total Credit Hours		**12**

Computer Science (CS) Courses

CS 5013. Fundamentals of Software. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science or consent of instructor. This course is a bridge course for graduate students who do not have a bachelor degree in Computer Science. It cannot be applied to the graduate degrees in computer science. Topics include discrete math, advanced data structure and basic algorithms, such as binary tree and stack, as well as system programming basics and concepts of compilation. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5023. Fundamentals of Systems. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science or consent of instructor. This course is a bridge course for graduate students who do not have a bachelor degree in Computer Science. It cannot be applied to the graduate degrees in computer science. Topics include basic concepts and knowledge in computer organization, architecture, operating systems and compilers. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5103. Software Engineering. (3-0) 3 Credit Hours.
Prerequisite: CS 4773 or software development experience. Introduction to methods and tools for the requirements analysis and design stages of software life cycles. Discussion of software requirements including elicitation, modeling notations, analysis, and documentation. Brief overview of process models and project management. Examination of major architectural styles in existing software systems, design methods, design patterns, and reverse engineering. Course will include design experience using CASE tools. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5113. Computer Graphics. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 and MAT 2233. Topics include display device coordinate system, 2D and 3D geometric transformations, scene interaction and animation, algorithms for drawing primitives such as lines, circles, curves and polygons, perspectives in 3D, hidden-line elimination, interactive lighting models, shadow generation, rendering and global illumination. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5123. Software Testing and Quality Assurance. (3-0) 3 Credit Hours.
Prerequisite: CS 4773 or software development experience. Introduction of testing techniques for software systems: unit testing, integration testing, system testing, acceptance testing, and regression testing; test plan and test case design; quality assurance; verification and validation. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5153. User Interfaces and Usability. (3-0) 3 Credit Hours.
Prerequisite: CS 4773 or software development experience. This course focuses on the development of high-quality user interfaces. The course reviews the basics of user interface development, tools, and use-case driven design techniques; examines the elements of good design and usability, metrics for usability, and procedures for user testing. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5163. Data Science. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. This course covers the fundamentals of data science. Topics include data management, data pre-processing, data visualization, data dissemination, and the mathematical and statistical foundations for data modeling. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5173. Steganography. (3-0) 3 Credit Hours.
Prerequisite: CS 3424 or consent of instructor. Steganography is the science of hiding secret data within innocuous data. This course covers a broad set of background topics including data compression, encryption, hashing, number theory, and human perception. It will also cover techniques for data hiding using image and audio files (e.g., bitmaps, jpegs, and wave files). The course will also explore steganalysis—the detection of hidden data—in various file types. It will also discuss the use of steganography in practice, particularly use by malware. The course includes a course project where a team of students develop and test their own steganography program. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5183. Software and Malware Reverse Engineering. (3-0) 3 Credit Hours.
Prerequisite: CS 3843, and CS 3113 or CS 3433, or consent of instructor. Reverse engineering in the context of computing is a process through which one attempts to understand how an existing computing system (hardware or software) accomplishes a task or functionality with very little insight, if any, into exactly how it does so. This course provides an introduction to the basic processes and procedures used for reverse engineering of software, hardware and malware. This includes a review of the hexadecimal/decimal/binary numbering systems, two's complement representation, basic logic functions and how they apply to reverse engineering, 32 bit x86 assembly language, stack structure, memory layout and little endian representation. It introduces students to tools for static disassembly such as hex editors, IDA Pro and Ghidra, dynamic debugging using Visual Studio, WinDbg, and other dynamic debugging tools, and binary reversing by covering the PE file format and advanced obfuscation techniques. It discusses relevant advanced topics such as data compression, steganography, forensics, and network analysis. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5233. Artificial Intelligence. (3-0) 3 Credit Hours.
Prerequisite: CS 3343. This course covers the construction of programs that exhibit intelligence in solving problems. Major topics include searching, game playing, constraint satisfaction, decisions and probabilistic reasoning, machine learning, neural networks, computer vision and natural language understanding. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5243. Computer Vision. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 and MAT 2233 or an equivalent or consent of instructor. Topics include image formation, geometry and transformations, multi-view geometry and 3D reconstruction, camera calibration, feature detection and matching, estimation and tracking, image classification, object detection, and scene understanding. This course has Differential Tuition. Course Fees: GS01 $90; IUCS $45.

CS 5263. Bioinformatics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science or consent of instructor. Introduction to bioinformatics. Problem areas such as sequence analysis and gene component analysis, structure prediction, gene ontology, phylogenetic inference, gene regulation, and pathway construction and analysis will be approached from a computational viewpoint. (Same as BME 6323. Credit cannot be earned for both BME 6323 and CS 5263.) This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5323. Principles of Cybersecurity. (3-0) 3 Credit Hours.
Prerequisite: CS 3733 and CS 3873. An introduction to the protection of computer systems and networks. Topics include authentication, access controls, malicious logic, formal security methods, assurance and trust in computer systems and networks, firewalls, auditing and intrusion detection, cryptography and information hiding, risk management, computer forensics, and ethics. (Formerly titled Principles of Computer and Information Security.) This course has Differential Tuition. Course Fees: GA02 $90.

CS 5343. Developing Secure Systems and Software. (3-0) 3 Credit Hours.
Prerequisite: CS 3733. An examination of methods for designing secure computer systems, networks, and software. Topics include the security development process, security policies and models, threat modeling, security code reviews and testing, the formal verification process, validation, and assessments. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5353. Formal Languages, Automata, and Theory of Computation. (3-0) 3 Credit Hours.
Prerequisite: CS 2233 and CS 3343. Formal models of computation and syntax such as Turing machines, finite automata, non-determinism, formal languages, regular and context free grammars, complexity classes and NP-completeness. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5363. Programming Languages and Compilers. (3-0) 3 Credit Hours.
Prerequisite: CS 2233 and CS 3343. A study of programming languages with an emphasis on their implementation. Topics include lexical analysis, language syntax, control structures, the binding of names, procedures, and their implementation in compilers. This course has Differential Tuition. Course Fees: GA02 $90.

CS 5443. Database Management Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 3743. Design and implementation of database management systems. Topics include storage management, query optimization, concurrency control, crash recovery, integrity, and security in relational databases, object-oriented databases, object-relational databases, parallel databases, and distributed databases. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

CS 5453. Penetration Testing. (3-0) 3 Credit Hours.
Prerequisite: CS 3873. Introduction to the principles and techniques associated with the cybersecurity practice known as penetration testing or ethical hacking. Topics include planning, reconnaissance, scanning, exploitation, post-exploitation, and result reporting. The student learns to use penetration testing tools, discover system vulnerabilities and avoid exploitation of vulnerabilities. This course has Differential Tuition. Course Fees: GA02 $90.

CS 5463. Topics in Computer Science. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science or consent of instructor. Topics in an area of computer science. May be repeated for credit when topics vary. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5473. Data Mining. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. Concepts, principles, algorithms, performance, and applications of data mining and knowledge discovery. Topics may include data preprocessing, classification and prediction, clustering analysis, association and pattern analysis, outlier detection, and data mining software. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5483. Topics in Data Science. (3-0) 3 Credit Hours.
Prerequisite: CS 5163. Specialized topics in an area of data science. May be repeated for credit when topics vary. (Credit cannot be earned for both CS 5483 and CS 4973 on the same topic). This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5493. Large-Scale Data Management. (3-0) 3 Credit Hours.
Prerequisite: Graduate student standing in Computer Science or permission of instructor. Modern big data systems managing 3 Vs of big data (variety, volume, and velocity). Topics include, but not limited to overview of classic data management, web search, information retrieval, MapReduce, data integration, natural language processing at scale. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5513. Computer Architecture. (3-0) 3 Credit Hours.
Prerequisite: CS 3733 and CS 3853. Study of modern computer architecture, including parallel computers, multiprocessors, pipelines, and fault tolerance. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 5523. Operating Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 3733 and CS 3853. Operating systems concepts with an emphasis on distributed systems. Topics include process management and threads, inter-process communication, distributed objects and remote invocation, distributed naming and directory services, distributed file systems, middleware such as CORBA, access control and security. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5573. Cloud Computing. (3-0) 3 Credit Hours.
Prerequisite: CS 3733 and CS 3853. Introduction to Cloud Computing. A study of the system architecture, enabling technologies, software environment, and innovative applications of the Cloud Computing paradigm. Topics include data center virtualization, cloud platforms, cloud resource management, cloud programming and software environments, big data processing in the cloud, cloud performance and energy efficiency analysis. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5593. Multi-Agent Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 5233. This course covers the theory and the approaches where more than one autonomous agent interacts with each other either in a cooperative or competitive manner. Topics include agent theory, agent architecture, agent communication, agent interaction, team organization, distributed rational decision making, and learning in multi-agent environment. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5623. Simulation Techniques. (3-0) 3 Credit Hours.
Prerequisite: CS 2123 or equivalent, and any statistics course. This course introduces discrete-event simulation techniques, statistical models in simulation, random number generation, input modeling, output analysis and comparisons, and verification and validation of simulation models. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5633. Analysis of Algorithms. (3-0) 3 Credit Hours.
Prerequisite: CS 3343. Models of computation and algorithm design and analysis techniques such as divide-and-conquer, greedy algorithms, dynamic programming, graph algorithms, amortized analysis. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5713. Practical Attack and Defense Techniques. (3-0) 3 Credit Hours.
Prerequisite: CS 5323. This course will provide a comprehensive hands-on experience on various open-source software tools and techniques for conducting information gathering, vulnerability analysis, web application analysis, password cracking, wireless attacks, network sniffing and spoofing, software exploits and reverse engineering, social engineering, forensics and post-exploitation services. This course has Differential Tuition. Course Fee: GS01 $90.

CS 5723. Crypto Currencies and Bitcoins. (3-0) 3 Credit Hours.
Prerequisite: CS 5323 or any introductory graduate level information/cybersecurity course. Study of public permission-less blockchains and its applications with an emphasis on Bitcoins. Topics include Blockchain fundamentals, Operation of the Bitcoin cryptocurrency, Bitcoin security, User privacy and anonymity in Bitcoin, Bitcoin as a distributed application platform, Bitcoin and cryptocurrency regulation, Future of Bitcoins and cryptocurrencies, Ethereum and Smart Contracts. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5733. Privacy Enhancing Techniques. (3-0) 3 Credit Hours.
Prerequisite: CS 5323 or permission of instructor. This course will introduce theoretical foundations and practical implementations of the various state-of-the-art privacy enhancing techniques (PETS) that provide web anonymity, location privacy, data privacy, social network privacy and other forms of contextual privacy in traditional web, mobile, internet of things (IoT) and cyber-physical system (CPS) applications. This course has Differential Tuition. Course Fees: GA02 $90.

CS 5813. Cognitive Neuroscience Inspired Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science or consent of instructor. Study of applying mathematical and computational methodologies toward understanding the human mind, brain and behavior, along with fundamentals of machine learning. Topics include but not limited to (1) Fundamentals for underpinning perception, language, attention mechanisms 2) Cognitive processes of learning and memory 3) Psychology research methods 4) the future applications using cognitive-inspired intelligence ranging from public health to cybersecurity. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5823. Trust, Confidence and Explainability in Artificial Intelligence. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. Study of fundamental methods for understanding strengths and weaknesses of machine learning and AI algorithms, including convolutional networks, recurrent neural networks, transformers and perceivers. Topics for explainability include attribution methods for AI, such as those based on gradients, Hessians, path integrals and Shapley values. Topics in trust and confidence include Platt scaling, temperature scaling, Bayesian networks and more modern calibration approaches based on attributions. Notions such as adversarial attacks, out-of-distribution (OOD) detection, and GANs will be discussed in the context of AI robustness. All concepts will be illustrated using real-world examples from both archival and contemporary literature. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5893. AI Practicum. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This AI practicum course includes weekly AI seminar which provides insights on the current state of the AI and ML technologies and covers a wide variety of AI topics, such as computer vision, natural language processing (NLP), theoretical ML, AI fairness & ethics, cognitive science, AI hardware, etc. The seminars will include speakers from industry and academia, who discuss the state of the practice with real use cases and methodologies to make AI projects a tangible success. The practicum also offers an experiential training opportunity to apply AI to problems in the real world. Standard AI programming tool suites and design flow concepts will be learned through the mini-project. Students will also be introduced to how AI is impacting society, the ethics of AI solutions, concerns surrounding AI, and deploying AI in complex scenarios. Python programming experience is needed. This course has Differential Tuition. Course Fee: IUCS $45; GS01 $90.

CS 5931. Internship in Computer Science. (0-0) 1 Credit Hour.
Prerequisite: An overall 3.0 grade point average, and permission in writing from the instructor, the Department Chair, and the Dean of the College of Sciences. This internship is an opportunity for a semester-long work experience in a private business or public agency in a computer science-related position. Not more than 3 semester credit hours of CS 5931 or CS 5933, and not more than a total of 6 semester credit hours of CS 5931, CS 5933, and CS 6953 may count toward the Master of Science degree or Ph.D. degree in Computer Science. The grade report for this course is either "CR" (satisfactory participation in the internship) or "NC" (unsatisfactory participation in the internship). This course has Differential Tuition. Course Fee: GS01 $30; IUCS $15.

CS 5933. Internship in Computer Science. (0-0) 3 Credit Hours.
Prerequisite: An overall 3.0 grade point average, and permission in writing from the instructor, the Department Chair, and the Dean of the College of Sciences. This internship is an opportunity for a semester-long work experience in a private business or public agency in a computer science-related position. Not more than 3 semester credit hours of CS 5931 or CS 5933, and not more than a total of 6 semester credit hours of CS 5931, CS 5933, and CS 6953 may count toward the Master of Science degree or Ph.D. degree in Computer Science. The grade report for this course is either "CR" (satisfactory participation in the internship) or "NC" (unsatisfactory participation in the internship). This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 5971. Directed Research. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing in Computer Science and permission in writing (form available) from the instructor and the Graduate Advisor of Record. The directed research course may involve either a laboratory or a theoretical problem. May be repeated for credit, but not more than 6 hours of CS 5971, CS 5972, CS 5973, and CS 6953, regardless of discipline, will apply to a degree. This course has Differential Tuition. Course Fee: GS01 $30; IUCS $15.

CS 5972. Directed Research. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing in Computer Science and permission in writing (form available) from the instructor and the Graduate Advisor of Record. The directed research course may involve either a laboratory or a theoretical problem. May be repeated for credit, but not more than 6 semester credit hours of CS 5971, CS 5972, CS 5973, and CS 6953, regardless of discipline, will apply to a degree. This course has Differential Tuition. Course Fees: GS01 $60; IUCS $30.

CS 5973. Directed Research. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science and permission in writing (form available) from the instructor and the Graduate Advisor of Record. The directed research course may involve either a laboratory or a theoretical problem. May be repeated for credit, but not more than 6 semester credit hours of CS 5971, CS 5972, CS 5973, and CS 6953, regardless of discipline, will apply to a degree. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 6133. Software Specification and Verification. (3-0) 3 Credit Hours.
Prerequisite: CS 5103. This course introduces the theory and practice of formal methods for the specification and verification of computer-based systems. It emphasizes various techniques for modeling behavior of sequential and concurrent systems and reasoning about properties of models using automated analysis tools. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $7.20.

CS 6243. Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. This course is a study of fundamental concepts and methods of machine learning. The strengths, weaknesses, and challenges of several machine learning algorithms will be covered. Topics include regression analysis, support-vector machine, dimensionality reduction, clustering, decision tree, k-nearest neighbor, neural networks, and other advanced topics selected by the instructor. This course has Differential Tuition. Course Fees: GS01 $90; IUCS $45.

CS 6263. Natural Language Processing. (3-0) 3 Credit Hours.
Prerequisite: CS 6243 or consent of the instructor. This course will explore various algorithms, topics, and applications related to natural language processing. The topics such as N-gram language models, Sentiment Classification, Vector Semantics, Embedding, Sequence Labeling, Parsing, and Coreference Resolution will be explored. Moreover, this course will cover a range of NLP applications such as Automatic Speech recognition and Text-to-Speech, Chatbots and Dialogue Systems, Question Answering, Machine Translation, Recommender Systems, etc. This course will also cover how the blending of statistical techniques and neural networks continues to provide performance gain for NLP tasks. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 6273. Parallel Algorithms. (3-0) 3 Credit Hours.
Prerequisite: CS 3343. Study of various design techniques and representative algorithms on shared memory and network models of parallel computation, and possibly, a few emerging topics in distributed and network computing arena. Topics may include algorithms for sorting, searching, selection, trees, graphs, data structures, etc., and new and emerging models and applications. This course has Differential Tuition. Course Fee: GS01 $90.

CS 6283. Deep Learning. (3-0) 3 Credit Hours.
Prerequisite: MAT 2233 and CS 5163 or consent of instructor. This course studies machine learning techniques in the area of artificial intelligence. Topics include neural networks, convolution networks, recurrent neural networks (RNNs), LSTM, generative and adversarial models, model training and validation, model dropout, and learning algorithms. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 6313. Deep Reinforcement Learning. (3-0) 3 Credit Hours.
Prerequisite: CS 5233 and CS 6283, or consent of instructor. This course covers the theory and the approaches to building autonomous agents that learn to act and accomplish goals in dynamic environments. Topics include Markov decision processes (MDPs), learning behavioral policies, police gradients, policy iteration, value iteration, agent explorations vs. exploitation, Q learning, and DNN for RL. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6323. Cybersecurity Models and Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 5323 or permission of instructor. Advanced coverage of core cybersecurity and privacy principles, models and technologies, and their applications in designing and building practical scalable systems. Emphasis on recently deployed and emerging cyber technologies and applications. This course has Differential Tuition. Course Fee: GS01 $90.

CS 6333. Cybersecurity Data Analytics. (3-0) 3 Credit Hours.
Prerequisite: CS 4373. Study on analyzing cybersecurity data to extract useful cybersecurity intelligence and information. Topics may include intrusion detection methods, anomaly detection methods, adversarial machine learning, malware detection methods, adversarial malware detection methods, and time series methods. Emphasis is on explaining cybersecurity meanings of phenomena and properties exhibited by cybersecurity data. This course has Differential Tuition. Course Fee: GS01 $90.

CS 6343. Cyber Risk Management. (3-0) 3 Credit Hours.
Prerequisite: CS 5323. Real-world cyber defenders and chief information/cybersecurity officers often need to make decisions in both operations and investments. This course aims to prepare next generation cyber defenders and chief information/cybersecurity officers with the-way-of-thinking in coping with cyber risks and the state-of-the-art in cyber risk management and decision-making. This course aims to prepare students with the body of knowledge that is needed for accomplishing such tasks and understanding and managing cyber risks. The course systematically describes the various kinds of cyber risks, strategies for mitigating these cyber risks, methodologies for qualitative and quantitative cyber risk management, and principles and approaches for making cost-effective (if not optimal) decisions. This course has Differential Tuition. Course Fees: GA02 $90.

CS 6353. Network and System Security. (3-0) 3 Credit Hours.
Prerequisite: CS 5323 or permission of instructor. This course is a review of cryptographic primitives. Study of network security protocols at different network layers including but not limited to IPSec, SSL/TLS and Kerberos. Public-key infrastructure in theory and practice. Firewalls, virtual private networks, denial of service countermeasures, and intrusion detection. Identity, authentication and access management protocols, models and standards, and their practical applications. This course has Differential Tuition. Course Fees: GS01 $90; IUCS $45.

CS 6373. Applied Cryptography. (3-0) 3 Credit Hours.
Prerequisite: CS 5323. A course in applied cryptography with an emphasis on applying cryptographic techniques to solve real-world problems. Topics include a review of cryptographic primitives such as symmetric and asymmetric (public-key) cryptosystems, digital signatures, pseudo-random sequences, and hash functions. An emphasis will be placed on utilizing advanced protocols to solve problems such as key management in various environments and applications. This course has Differential Tuition. Course Fees: GA02 $90.

CS 6383. Quantum Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. This course covers quantum computing, qubits, and important illustrative examples of quantum algorithms such as Grover search and Variational Quantum algorithms. Data representations in quantum computers, such as amplitude encoding, time-evolution encoding, and Hamiltonian encoding. Variational Quantum Classifiers and quantum neural networks. Quantum kernels and kernel-based training. Ising models and quantum annealing. Fault-tolerance in quantum machine learning. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6393. Advanced Topics in Computer Security. (3-0) 3 Credit Hours.
Prerequisite: CS 5323. Analysis of computer security. The topics may include but are not limited to database and distributed systems security, formal models for computer security, privacy and ethics, intrusion detection, critical infrastructure protection, network vulnerability assessments, wireless security, trusted computing, and highly dependable systems. May be repeated for credit when topics vary. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6463. Advanced Topics in Computer Science. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science and consent of instructor. Advanced topics in an area of computer science. May be repeated for credit when topics vary. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6513. Advanced Architecture. (3-0) 3 Credit Hours.
Prerequisite: CS 5513 and CS 5523. Areas of study include advanced architectures, including massively parallel and distributed systems. Issues of communication, fault tolerance, and performance are addressed. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $7.20.

CS 6543. Networks. (3-0) 3 Credit Hours.
Prerequisite: CS 5523. This course introduces the underlying concepts and principles of modern computer networks, with emphasis on protocols, architectures and implementation issues in the internet. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6553. Performance Evaluation. (3-0) 3 Credit Hours.
Prerequisite: CS 5513 and CS 5523. This course introduces analytical modeling, simulation analysis, and experimental evaluation of computer systems and networks. Particular emphasis will be placed on the analysis and design of medium- to large-scale distributed computer systems and networks. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6643. Parallel Processing. (3-0) 3 Credit Hours.
Prerequisite: CS 5513. Parallel models of computation, performance measurement, and modeling of parallel algorithms and application studies on parallel computers. This course has Differential Tuition. Course Fee: GS01 $90; IUCS $45.

CS 6663. Advanced Parallel Processing and Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 5513 and CS 5523. An advanced parallel computing course focusing on large-scale data processing. Topics may include parallel processing with non-CPU processors (such as GPUs, FPGAs, Application-specific Circuits), large-scale Non-Uniform Memory Access architectures, parallel data-processing frameworks, non-volatile memory chips and large-scale public clouds. This course has Differential Tuition. Course Fee: GS01 $90.

CS 6953. Independent Study. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing in Computer Science and permission in writing (form available) from the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours of CS 5971, CS 5973, and CS 6953, regardless of discipline, will apply to a degree. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 6961. Comprehensive Examination. (0-0) 1 Credit Hour.
Prerequisite: Approval of the Graduate Program Committee to take the Comprehensive Examination. Independent study course for the purpose of taking the Comprehensive Examination. May be repeated as many times as approved by the Graduate Program Committee. Enrollment is required each term in which the Comprehensive Examination is taken if no other courses are being taken that term. The grade report for the course is either "CR" (satisfactory performance on the Comprehensive Examination) or "NC" (unsatisfactory performance on the Comprehensive Examination). This course has Differential Tuition. Course Fees: GA02 $30; IUCA $15.

CS 6981. Master's Thesis. (0-0) 1 Credit Hour.
Prerequisite: Consent of thesis advisor. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition. Course Fees: GA02 $30; LRAS $15.40; STAS $7.20; IUCA $15.

CS 6983. Master's Thesis. (0-0) 3 Credit Hours.
Prerequisite: Consent of thesis advisor. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 7123. Research Methods. (3-0) 3 Credit Hours.
Prerequisite: Doctoral Student standing. Examine and learn practical research skills and research writing techniques. Review, present, and critique recent research publications in the areas of Computer Science. May be repeated for credit. May not be counted towards the Master of Science degree in Computer Science. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 7211. Doctoral Research. (0-0) 1 Credit Hour.
Prerequisite: Doctoral Student standing and consent of Doctoral Advisor. May be repeated, a minimum of 18 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fees: GA02 $30; IUCA $15.

CS 7212. Doctoral Research. (0-0) 2 Credit Hours.
Prerequisite: Doctoral Student standing and consent of Doctoral Advisor. May be repeated, a minimum of 18 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fee: GS01 $60; IUCS $30.

CS 7213. Doctoral Research. (0-0) 3 Credit Hours.
Prerequisite: Doctoral Student standing and consent of Doctoral Advisor. May be repeated, a minimum of 18 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 7216. Doctoral Research. (0-0) 6 Credit Hours.
Prerequisite: Successful completion of the Doctoral Qualifying Examination. May be repeated, a minimum of 18 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fees: GA02 $180; IUCA $90.

CS 7311. Doctoral Dissertation. (0-0) 1 Credit Hour.
Prerequisite: Admission to candidacy for the Doctoral degree. May be repeated, a minimum of 9 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fees: GA02 $30; IUCA $15.

CS 7312. Doctoral Dissertation. (0-0) 2 Credit Hours.
Prerequisite: Admission to candidacy for the Doctoral degree. May be repeated, a minimum of 9 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fee: GS01 $60; IUCS $30.

CS 7313. Doctoral Dissertation. (0-0) 3 Credit Hours.
Prerequisite: Admission to candidacy for the Doctoral degree. May be repeated, a minimum of 9 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fees: GA02 $90; IUCA $45.

CS 7316. Doctoral Dissertation. (0-0) 6 Credit Hours.
Prerequisite: Admission to candidacy for the Doctoral degree. May be repeated, a minimum of 9 hours is required for the Doctoral degree. This course has Differential Tuition. Course Fees: GA02 $180; IUCA $90.