ARIZONA BOARD OF REGENTS
ASU ◆ NAU ◆ UA

Request to Establish New Academic Program in Arizona

Please complete all fields. Boxes may be expanded to accommodate longer responses. Clarifying field descriptions can be found below. Should you have any questions or concerns, please email Helen Baxendale, Director of Academic Affairs and Policy at helen.baxendale@azregents.edu

University:

Name of Proposed Academic Program:

- PhD Computer Science and Engineering (CSE)

Academic Department:
The name of the academic department or unit that will primarily administer the academic program. If the proposed program will be jointly administered across more than one department, please list the(se) additional department(s).

- College of Engineering: 2303 - Electrical and Computer Engineering

Geographic Site:
The physical site (campus, extended campus, etc.) or modality where the academic program will be primarily delivered or administered.

- Main Campus (Tucson)

Instructional Modality:
The primary modality of the academic program (i.e. immersion, online, hybrid).

- In-person immersion

Total Credit Hours:
The number of credit hours required to complete the academic program

- 63 units

Proposed Inception Term:
The term and year in which the program will be first delivered (i.e. Spring 2021; Fall 2022).

- Fall 2024

Brief Program Description:
A short outline of the content and skills that the proposed program will deliver. A brief description of how the program fits into the institutional mission of the university. If relevant, please provide succinct information about existing related or complementary academic programming.

The doctoral program in Computer Science and Engineering will provide a unique opportunity for students to deepen their knowledge of computer science and engineering topics by combining theory-based concepts with advanced, enabling computational techniques and technologies to create solutions that address the grand challenges of the 21st century, and beyond. The curriculum applies computer science theory and software development fundamentals to produce computing-based solutions. It includes substantial coverage of

engineering principles applied to the design of large, networked, scalable computing systems. Competencies include algorithms and complexity, concepts of multiple programming languages, software development, real-time, embedded, and IoT systems design and other broad-based engineering principles.

The PhD curriculum offers highly advanced, specialized, and integrative curriculum in these topics paired with an advanced research component that culminates in a high-impact, archival doctoral dissertation, and the potential to have publications in peer-reviewed journals with substantial contribution to the research community. The program has a firm engineering foundation that encompasses discovery-based education utilizing an experiential learning approach. As a part of the curriculum, students will complete projects and novel research in areas that emphasize computing theory, communication, teamwork, critical thinking, and engineering professionalism, that culminate in scholarly products including a dissertation and other published works. The PhD program's flexibility allows students to design their course of study / research from a diverse pool of courses and research opportunities in software, computer science and computer engineering domains such as web and mobile applications, embedded systems, cybersecurity, machine learning, Quantum computing, systems, and other interdisciplinary areas.

Learning Outcomes and Assessment Plan:
Define the core concepts and competencies that the program will convey and stipulate how these key learning outcomes will be measured and assessed.

Learning Outcome #1: *Demonstrate broad knowledge in student's field in Computer Science and Engineering.*
Concepts: Study diverse topics in computer science and engineering in the topic areas such as Systems and Applications, Theory of Computation, and Knowledge and Data Engineering, and others. Students have the option to select from a broad range of software, electrical engineering and computing related technical electives. Courses may include computing topics such as operating system design, compiler design, analysis of algorithms for engineering applications, advanced data structures, database/data engineering, cloud computing, robotics and a variety of other computing topics that vary based on the electives the student opts to take.
Competencies: Demonstrate the ability to research, design, develop, test, integrate and evaluate varied software applications/products/systems in diverse computing and engineering domains. Students opting for the *Thesis-Option* to satisfy their course requirements may also apply their acquired knowledge in these areas to conduct original and novel research in state-of the-art and advanced computer science and engineering principles, processes, and methodologies to meet the requirements/needs of diverse engineering applications.
Assessment Methods: For every new 5xx / 6xx CSE course, a rubric will be created that identifies criteria/source of evidence, assessment measures, and an achievement level rating for specified course performance indicators used to measure this outcome. For each course that contributes to this outcome, specific student artifacts for a given course will be evaluated and assessed. The sources of evidence can include class assignments, exams, projects, papers / reports and other forms of student work. For new courses, the specific evidence used will be defined as the course is developed and re-evaluated as part of the continuous improvement activities for the program/course. For existing courses (predominately technical electives), the

evidence used to measure the effectiveness of the student outcome have been defined and will be followed. The rubric achievement levels will include: "Exemplary", "Satisfactory", "Developing", and "Unsatisfactory". At the end of every semester, a team comprised of the course instructor and the ECE Graduate Studies Committee (GSC), will score the rubric using the assessment measures identified for the course. A root cause and corrective action plan will be developed for any course that scores "Developing" or below. Assessment results are documented and formally maintained in a controlled location at the end of each semester and will be published as appropriate. The scores will be tracked over time to facilitate the continuous improvement and corrective action plans remain effective from semester to semester, year to year.
Measures: Rubrics will be used for the specific graded student artifact for a given course that clearly evaluates the learning objectives and outcomes of the assignment and/or projects that students are asked to complete. All rubrics are developed by faculty members with expertise in computing domains. Faculty may consult with instructional designers as appropriate to ensure the course learning outcomes are measurable and contribute to the overall program learning outcomes. Exams are also used to assess and measure student learning. Throughout the degree program, the student's core course cumulative GPA will be used as a global measure of the overall student CSE knowledge. Additionally, the student's score on the Doctoral Qualifying Exam (DQE) is used to assess the student's fundamental knowledge in specific CSE domains and whether students have a comprehensive understanding of the concepts and theories taught in those domains. The student's score on the Doctoral Comprehensive Exam will also be used to measure the student's background and expertise in the field of their research / dissertation. An exit survey will also be used to measure this outcome after doctoral students have completed their studies/research.
Learning Outcome #2: Critically analyze and review published research results and other literature related to the student's area of study.
Concepts: Synthesize various research techniques to interpret methods used and results from computing related research papers, journals, presentations, and/or conferences. Throughout the program, students will have the opportunity to attend several seminars presented by a diverse group of researchers / scholars and faculty from a broad spectrum of software and computing related fields/areas. They will learn techniques used to critically read published research papers/journals, explore writing techniques used in technical/academic works, learn to develop evidence-based arguments, and draw conclusions from the sources being reviewed. They will also be provided with numerous resources and learn to develop strategies for acquiring and using technical references from a variety of sources.
Competencies: Demonstrate the ability to read and interpret various forms of computing research information, papers, conference proceedings, and data collected to support research. Students will also demonstrate their understanding of techniques used to write technical papers and journal articles. Students will also be able to analyze and explain research approaches taken and results included in published computing research papers, journals and conference proceedings.
Assessment Methods: This outcome will be assessed in CSE related research papers written and submitted to various technical publications and journals or conferences. If the student elects the MS Thesis option as part of their plan of study, the thesis project under the guidance of a faculty advisor, is reviewed by

an examining committee prior to an oral presentation. This learning outcome is also assessed via the written Doctoral Comprehensive Exam which includes a dissertation proposal related to the students CSE area of specialization. The written exam is followed by an Oral Comprehensive Exam which is held with a review committee and typically contains a presentation based on the proposed dissertation research.
Measures: Instructor grading of research related coursework in CSE 507, results from a student's thesis defense using the collective results of a Program Assessment Survey completed by various thesis committee members, and the results of the student's final oral defense of their dissertation.
Learning Outcome #3: *Conduct in-depth original research in a computer science and engineering application area/field.*
Concepts: Utilize acquired knowledge and new research strategies to conduct novel research in a computer science and engineering field of specialization. Students will meet regularly with their faculty advisor and others within the ECE department to receive guidance and coaching in a variety of research areas. Students will summarize all aspects of their research and their findings in a written dissertation that will be defended orally before a faculty committee appointed by the Dean of the Graduate College.
Competencies: Demonstrate the ability to articulate all aspects of their research in a CSE specialization area, describe and defend the significance of their research, describe methodologies used in conducting the research, and summarize their overall findings resulting from said research.
Assessment Methods: A dissertation committee will assess the originality, merit, and contributions of the candidate's research. The written dissertation and oral defense is facilitated by a faculty committee appointed by the Dean of the Graduate College in consultation with the major department and chaired by the faculty advisor. The presentation portion of the oral defense is open to the public. Following the public presentation and discussion, the candidate will participate in a closed meeting with the committee for further evaluation.
Measures: Evaluation of the student's final written dissertation. The dissertation will be evaluated by a faculty led committee that assesses the originality, merit, and contributions of the candidate's research. This includes their ability to (a) identify and critically evaluate relevant literature, (b) formulate and solve original problems using computational theory and methods, and (c) interpret and communicate research ideas, data and findings.
Learning Outcome #4: *Communicate and defend (written and oral) results of projects or research to peers and broader engineering audiences.*
Concepts: Utilize their acquired CSE skills and knowledge to communicate effectively in both written and oral mediums. This may be accomplished in a variety of methods including submitting research papers to technical journals, submitting / presenting at technical conferences, and/or presenting their research to others via seminars and colloquium presentations. Additionally, doctoral candidates will prepare a written dissertation that demonstrates all aspects of their research including the significance of their work, a detailed review of relevant literature, methodologies employed and/or developed, significant findings from the work, a critical discussion of the findings, limitations, and the impact, and potential for future research. When the doctoral candidate has met the rigor and standards of scholarship and has documented the research in a dissertation, the candidate will publicly defend the dissertation and answer any questions related to their work.

Competencies: Demonstrate their ability to articulate all aspects of the research in a computer science and engineering specialization area, describe and defend the significance of their research, describe methodologies used in conducting the research, and summarize their overall findings resulting from said research.
Assessment Methods: A dissertation committee will assess the originality, merit, and contributions of the candidate's research. The written dissertation and oral defense is facilitated by a faculty committee appointed by the Dean of the Graduate College in consultation with the ECE department and chaired by the faculty advisor. The presentation portion of the oral defense is open to the public. Following the public presentation and discussion, the candidate will participate in a closed meeting with the committee for further evaluation.
Measures: Evaluation of the student's final written and oral dissertation. The dissertation will be evaluated by a faculty led committee that assesses the originality, merit, and contributions of the candidate's research. This includes their ability to (a) identify and critically evaluate relevant literature, (b) formulate and solve original problems using computational and engineering theory and methods, and (c) interpret and communicate research ideas and findings.

The Taskstream Curriculum Map is shown below. Note that the assessment plan includes only new CSE courses that are part of this program. Existing ECE courses used to fulfill the degree requirements are not included. The assessment plans for existing courses will be followed per the department's assessment plan for each respective existing course.

PhD Computer Science and Engineering

Courses and Activities Mapped to PhD Computer Science and Engineering

	Outcome			
	SLO 1 Demonstrate broad knowledge in the student's field in Computer Science and Engineering.	SLO 2 Critically analyze and review published research results and other literature related to the student's area of study.	SLO 3 Conduct in-depth original research in a computing application area / field.	SLO 4 Communicate and defend (written and oral) results of projects or research to peers and broader engineering audiences.
Courses and Learning Activities				
CSE 501 Operating System Design (Core Elective)	P/A			
CSE 503 Analysis of Algorithms for Engineering Applications (Core Elective)	P/A			P/A
CSE 504 Embedded Systems Computing (Core Elective)	P/A			
CSE 505 Advanced Data Structures (Core Elective)	P/A			
CSE 506 Database Engineering (Core Elective)	P/A			
CSE 507 Computer Science and Engineering Research Methods (Core Elective)	P/A	IPA	I	IPA
ECE 695 Colloquium (Required)		P/A		
CSE 920 Dissertation Research (Required)	P/A	P/A	P/A	P/A
CSE 502 Compiler Design (Computing Elective)	P/A			
CSE 900 Research (Computing Elective)	P/A	P/A	P/A	P/A
Exit Survey Exit survey (Indirect)	A	A	A	A

Legend: I Introduced | P Practiced | A Assessed | I/P Introduced/Pract

Assessment Measure	Source(s) of Evidence	Data Collection Point(s)
Rubrics for all new courses used to assess each student outcome that identifies criteria, measure of assessment, and an achievement level rating *(i.e., Exemplary, Satisfactory, Developing, Unsatisfactory).*	Specifically targeted: • Class assignments • Exams • Course Projects • Course Reports • Other forms of student work tailored to any specific course)	End of each semester the specific courses are taught.
Doctoral Qualifying Exam (DQE)	• Students grades in CSE graduate level courses taken during the first year of their studies. • Score on the DQE	This exam is administered at the start of every academic year. Students are required to take the exam at the start of their second year in the program.
Doctoral Comprehensive Exam	• Written Comprehensive Exam score • Oral Comprehensive Exam score	The comprehensive exam is typically taken at least a semester to a year before the final dissertation defense. It is recommended that the comprehensive exam is taken at least nine months before the final defense.
Doctoral Final Written Dissertation	Written Dissertation	Published and evaluated at the conclusion of the candidate's doctoral research efforts to assess the merit and contributions of the candidate's doctoral research.
Doctoral Oral Dissertation Defense	Oral Defense of the student's Dissertation	When the doctoral candidate has met the rigor and standards of scholarship and has documented the research in a dissertation, the candidate will publicly defend the dissertation and answer any general questions related to their work.
Graduation exit survey (used for indirect measures of outcomes).	Student survey	At student graduation

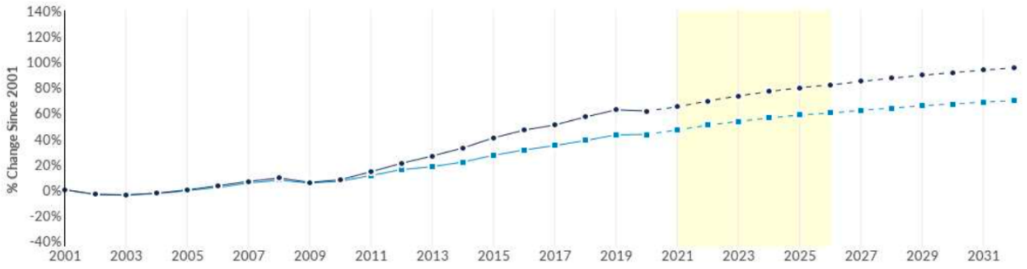
Projected Enrollment for the First Three Years:
Please provide anticipated enrollment numbers for each of the first three years of the proposed program

Degree	Year 1 (2024 / 2025)	Year 2 (2025 / 2026)	Year 3 (2026 / 2027)

PhD	5	15	30

Evidence of Market Demand:
Please provide an estimate of the future state-wide and national demand for graduates of the proposed academic program. Please specify the source (e.g. Burning Glass; Jobs EQ; US Department of Labor) of workforce demand data and detail the assumptions that underpin these projections. If job market data is unavailable or not applicable please explain why and elaborate another justification for the proposed program.

The market demand for those trained in engineering computing disciplines is projected to have significant growth in both the near- and long-term futures. Specifically, the chart below shows the growth in computing-related jobs up to 2021, as well as the projected growth through 2033, both regionally (Arizona, California, Nevada, New Mexico, Utah) and nationally[1].



Region	2021 Jobs	2026 Jobs	Change	% Change
Region	1,010,147	1,115,128	104,981	10.4%
Nation	5,406,515	5,892,114	485,599	9.0%

Note that computing-related job growth within our region is projected to grow at a faster pace than the nation as a whole. Thus, the new MS and PhD degree programs will serve both local, state, and national needs related to employment, economic development, and national security. Indeed, these degree programs are among the most important in support of the ongoing fourth industrial revolution and in close alignment with Arizona's New Economy Initiative[2].

The full marketing and analysis report for the state of Arizona can be found at the following link: https://arizona.box.com/s/k4d8cj657sqv6bban2yyi4gcf0paqi0e

The full marketing and analysis report for the nation can be found at the following link: https://arizona.box.com/s/stizctd27mfeltaxsv2ylmgfa8zgsoco

Similar Programs Offered at Arizona Public Universities:
List existing programs at Arizona public universities that deliver similar concepts and competencies to the proposed new program.

[1] Emsi Q2 2022 Data Set, www.economicmodeling.com
[2] World Economic Forum. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

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University	Program	College
University of Arizona	MS Computer Science PhD Computer Science	College of Science
Arizona State University	MS Computer Science PhD Computer Science	School of Computing and Augmented Intelligence, IRA A Fulton Schools of Engineering
Northern Arizona University	MS Computer Science PhD Information and Computing	School of Informatics, Computing, and Cyber Systems

Objection(s) Raised by Another Arizona Public University? YES NO
Has another Arizona public university lodged a written objection to the proposed program with the proposing university and the Board of Regents within seven days of receiving notice of the proposed program?

If Yes, Response to Objections:
Please provide details of how the proposing university has addressed the objection. If the objection remains unresolved, please explain why it is in the best interests of the university system and the state that the Board override it.

New Resources Required? (i.e. faculty and administrative positions; infrastructure, etc.):
Please provide an estimate of the personnel and infrastructure requirements of the proposed new program and the corresponding costs. Please specify if the proposed program requires new resources (e.g. new faculty lines; a new laboratory; new teaching assistantships or scholarships) or whether resource needs may be met through the reassignment or extension of existing ones. If resource extension or reassignment will impact extant programs and/or operations, please make this clear.

The table below summarizes the additional resources required over the academic years 2023 – 2028.

Resources	Quantity
Faculty	**4**
Staff	**0**
Other (TAs, Graders, LAs) *(Semester hires over next 5 academic years)*	• **0 TAs** • **0 Graders** • **0 LAs**
Equipment	• **New research and lab equipment is included in the startup packages for new TT faculty**
Facilities	• **Office and lab space** *(for new faculty)*

Plan to Request Program Fee/Differentiated Tuition? NO

Estimated Amount: N/A

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Program Fee Justification: N/A
If planning to levy a program fee, please justify the estimated amount.

Note: The fee setting process requires additional steps, and forms need to be completed. Please work with your university and the ABOR Finance team (Leatta.McLaughlin@azregents.edu) to complete a fee request.

Specialized Accreditation? NO

Accreditor: N/A