THE UNIVERSITY OF ARIZONA®

New Academic Program Workflow Form

General

Proposed Name: Software Engineering

Transaction Nbr: 00000000000162

Plan Type: Major

Academic Career: Graduate

Degree Offered: Doctor of Philosophy

Do you want to offer a minor? N

Anticipated 1st Admission Term: Fall 2023

Details

Department(s):

ENGR

DEPTMNT ID	DEPARTMENT NAME	HOST
2302	Systems & industrial Engineering	Y
2303	Electrical & Computer Engr	N

Campus(es):

MAIN

LOCATION	DESCRIPTION
TUCSON	Tucson

ONLN

LOCATION	DESCRIPTION
ONLN	Online

Admission application terms for this plan: Spring: Y Summer: Y Fall: Y

Plan admission types:

Freshman: N Transfer: Y Readmit: Y Graduate: Y

Non Degree Certificate (UCRT only): Y

Other (For Community Campus specifics): N

Plan Taxonomy: 14.0903, Computer Software Engineering.

Program Length Type: Program Length Value: 0.00

Report as NSC Program:

SULA Special Program:

Print Option:

Diploma: Y PhD Software Engineering

Transcript: Y PhD Software Enginering

Conditions for Admission/Declaration for this Major:

Applicants interested in pursuing a PhD must meet the following minimum requirements:

- A minimum 3.0 cumulative GPA in their overall undergraduate degree or meet Graduate College minimum admissions requirements.
- Hold a BS degree in math, physics, chemistry, or engineering or related field.

Students with BS degrees in disciplines not directly related to Software Engineering may be admitted into the MS or PhD program. PhD students who do not have a BS in Software Engineering must demonstrate competency in any prerequisite courses to graduate level software engineering courses. Students may take pre-requisite and co-requisite courses for audit or credit, or students learn the material from these courses on their own time to successfully pass the required prerequisites.

The following are suggestions for PhD students to satisfy prerequisites:
1. Provide proof (transcript and a description of the course) of satisfactorily completing equivalent coursework at an institution recognized by the University of Arizona.
2. Receive course credit by examination (consult with the Graduate Studies Committee) if allowed.

The SFWE doctoral program does not require applicants to have an MS degree to be admitted. Admitted PhD students have the option to earn a SFWE MS degree enroute to their PhD.

Requirements for Accreditation:

None

Program Comparisons

University Appropriateness

Two of the College of Engineering's strategic pillars are:

1) Driving student success for a rapidly changing world, and
2) Tackling critical problems at the edges of human endeavor

The new Software Engineering MS and PhD degree programs play a critical role in both pillars. The students graduating with a MS or PhD in Software Engineering degree will be better positioned to develop the skills and mindsets to be leaders in the areas of software development, computing, machine learning, ever-increasing automation and connectivity, human and intelligent systems, data science, and network sciences.

By offering competitive, relevant, and experiential-based learning Software Engineering programs to prospective students, it increases not only the net enrollment in the college, but also the ability to grow research programs that are attractive to forthcoming undergraduate and graduate students. All of which contribute to higher recruitment numbers and bringing additional revenue to the College of Engineering and University at large. Hence, we will recruit faculty that can significantly impact software engineering and computing areas of research and education. As we have realized with recruitment for faculty in the undergraduate program in Software Engineering, having a graduate level program is also essential to recruit world-class faculty to the program. These faculty will pursue research grants to advance the state-of-the-art in applied software engineering and integrate their research into the curricula. The broader impact of these faculty will ultimately drive the program's national ranking higher.

While less obvious, another goal for the program is to increase the number of female and other underrepresented students in the College of Engineering by offering the Software Engineering graduate degrees. Additional features and programs that contribute to enhancing student success and increasing diversity and inclusion will also be included in the support infrastructure for the degree.

Arizona University System

NBR	PROGRAM	DEGREE	#STDNTS	LOCATION	ACCRDT
1	Computer Science	PHD	75	University of Arizona - Main	N
2	Computer Science	PHD	206	Arizona State University - PHX	N
3	Information and Computing	PHD	30	No Arizona Univ - Flagstaff	N

Peer Comparison

See attached document.

Faculty & Resources

Faculty

Current Faculty:

INSTR ID	NAME	DEPT	RANK	DEGREE	FCLTY/%
02600592	Kenneth Head	2302	Professor	Doctor of Philosophy	.25
03308095	Jerzy Rozenblit	2303	Professor	Doctor of Philosophy	.25
06606459	Michael Marefat	2303	Professor	Doctor of Philosophy	.25
10608029	Salim Hariri	2303	Professor	Doctor of Philosophy	.25
16600630	Loukas Lazos	2303	Professor	Doctor of Philosophy	.25
17109846	Jian Liu	2302	Assoc. Prof	Doctor of Philosophy	.25
22053534	Ricardo Valerdi	2302	Professor	Doctor of Philosophy	.20
22063694	Samuel Peffers	2302	Assoc. Prof. Pract.	Doctor of Philosophy	.25
22067654	Ravi Tandon	2303	Professor	Doctor of Philosophy	.25
22067655	Tosiron Adegbija	2303	Professor	Doctor of Philosophy	.25
22071369	Vignesh Subbian	2302	Assoc. Prof	Doctor of Philosophy	.25
22072066	Sharon O'Neal	2302	Prof. Pract.	Master of Science	.25
22092594	Fredrick Steiner	2302	Lecturer	Master of Science	.25
22094595	Mohammad Abu matar	2303	Assoc. Prof. Pract.	Doctor of Philosophy	.50
22095228	Abhijit Mahalanobis	2303	Assoc. Prof	Doctor of Philosophy	.25
22095632	Soheil Salehi Mobarakeh	2303	Assit. Prof	Doctor of Philosophy	.25
23190064	Pratik Satam	2302	Assit. Prof	Doctor of Philosophy	.50

Additional Faculty:

In the first 5 years of the program, it is projected that the following Tenure Track faculty will be required (total of 2):

2023/2024 - 0
2024/2025 - 0
2025/2026 - 0
2026/2027 - 1
2027/2028 - 1

Current Student & Faculty FTE

DEPARTMENT	UGRD HEAD COUNT	GRAD HEAD COUNT	FACULTY FTE
2302	325	210	27.50
2303	465	305	48.00

Projected Student & Faculty FTE

	UGRD HEAD COUNT			GRAD HEAD COUNT			FACULTY FTE		
DEPT	YR 1	YR 2	YR 3	YR 1	YR 2	YR 3	YR 1	YR 2	YR 3
2302	325	400	475	230	260	310	30.00	32.00	33.00
2303	465	595	765	310	325	355	55.00	60.00	64.00

Library

Acquisitions Needed:

There are no anticipated additional library acquisition needs with the Software Engineering degree program.

Physical Facilities & Equipment

Existing Physical Facilities:

Students and faculty for the proposed Software Engineering degree program will utilize the existing classrooms, laboratories, computer facilities, physical equipment that is currently available to all Engineering majors; in particular the Electrical and Computer Engineering Department and the Systems and Industrial Engineering Department.

New laboratory equipment needed for Tenure Track faculty is included in estimated start-up packages and will vary depending on the nature of the research for acquired new faculty members.

Additional Facilities Required & Anticipated:

Many of the tools and lab facilities used by this degree program already exist for other courses offered within the ECE and SIE departments. Many software development tools traditionally used for software engineering courses are open source and readily available for faculty and students to use at little to no charge. Cloud based resources, such as those offered through Amazon Web Services (AWS) or Microsoft Azure, can host integrated development environments for courses that require more comprehensive integrations of multiple tool types of toolsets to support student projects. If there are licenses or cloud-based resource

usage fees that become necessary for different software engineering courses in the future, those costs could be included in course fees.

Office and laboratory space will be required for new faculty.

Other Support

Other Support Currently Available:

The College of ENGR and the SIE and ECE Departments are currently well structured and to be able to accommodate the new program, including IT support. Additional staff will be required and described below.

Other Support Needed over the Next Three Years:

There are no additional staff requirements to support the Software Engineering PhD program.

Comments During Approval Process

11/30/2022 3:56 PM

WILLIAMSCINDY

Comments
Remove Distance Campus.

1/9/2023 10:32 PM

RVALERDI

Comments
Approved.

THE UNIVERSITY OF ARIZONA

NEW ACADEMIC PROGRAM – MAJOR
Preliminary Proposal Form

I. **Program Details**

i. **Name (and Degree Type) of Proposed Academic Programs:** PhD Software Engineering
ii. **Emphases (if applicable):** None

b. **Academic Unit(s)/College(s):**
College of Engineering:
2303 - Electrical and Computer Engineering (50%) and
2302 - Systems and Industrial Engineering (50%)

c. **Campus/Location(s):** Main Campus (Tucson) and UArizona Online

d. **First Admission Term:** Fall 2023

e. **Primary Contact and Email:** Sharon ONeal *sharononeal@arizona.edu*

II. **Executive Summary:**

The future looks very promising for the software engineering discipline and profession. The global market of software engineering, alone, will be worth $64 billion by 2025, and it is a vital part of a bigger industry. The overall software market size was $567 million globally in 2020 and is projected to reach $1,021 million by 2025, projected to almost doubling in size within 5 years. Some of the factors behind this growth include increased automation in multiple industries, the demand for cloud-based solutions, the internet of things and an increase of devices which can be used in daily life for convenience. In response to this projected growth, we are proposing the creation of a PhD Software Engineering degree program at the University of Arizona, which is aligned with several UArizona strategic pillars.

UArizona launched its BS Software Engineering in Fall 2021, developing a strong pipeline of incoming students to the PhD program. As with the BS SFWE program, the proposed program will be co-hosted in the Electrical & Computer Engineering

(ECE) and Systems and Industrial Engineering (SIE) departments. The ECE and SIE departments already offer a rich array of courses that can be used as electives within the proposed programs.

The PhD SFWE programs will serve local, state, and national increasing needs in engineering computing talent related to economic development and national security and are aligned with Arizona's New Economic Initiative. The program will also support and enable the University of Arizona's growth goals / initiatives to increase student enrollments, research opportunities, and collaborations with our faculty and external entities.

III. **Brief Program Description:**

The MS Software Engineering curriculum applies software engineering fundamentals to develop and produce computing-based products/solutions. The MS SFWE program is grounded in solid engineering practices and principles governed by the IEEE Software Engineering Body of Knowledge (IEEE SWEBOK). IEEE SWEBOK recommends specific skills that all software engineers should possess regardless of their programming languages and platforms. Our curriculum focuses on the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software.

The PhD curriculum builds upon the MS Software Engineering program by adding additional coursework and research opportunities for students wishing to pursue a PhD in Software Engineering.

The PhD SFWE 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 in areas that emphasize software engineering, communication, teamwork, critical thinking, and engineering professionalism. Students will also conduct novel research in many diverse software engineering related areas. The program's flexibility allows students to design their course of study / research from a diverse pool of courses and research opportunities in software and computer engineering domains such as web and mobile applications, embedded systems, cybersecurity, machine learning, systems, and other interdisciplinary areas.

Program Rationale:

Two of the College of Engineering's strategic pillars are:

1) Driving student success for a rapidly changing world, and
2) Tackling critical problems at the edges of human endeavor

The new Software Engineering PhD degree program plays a critical role in both pillars. The students graduating with a PhD in Software Engineering degree will be better positioned to develop the skills and mindsets to be leaders in the areas of software development, computing, machine learning, ever-increasing automation and connectivity, human and intelligent systems, data science, and network sciences.

By offering competitive, relevant, and experiential-based learning Software Engineering programs to prospective students, it increases not only the net enrollment in the college, but also the ability to grow research programs that are attractive to forthcoming undergraduate and graduate students. All of which contribute to higher recruitment numbers and bringing additional revenue to the College of Engineering and University at large. Hence, we will recruit faculty that can significantly impact software engineering and computing areas of research and education. As we have realized with recruitment for faculty in the undergraduate program in Software Engineering, having a graduate level program is also essential to recruit world-class faculty to the program. These faculty will pursue research grants to advance the state-of-the-art in applied software engineering and integrate their research into the curricula. The broader impact of these faculty will ultimately drive the program's national ranking higher.

While less obvious, another goal for the program is to increase the number of female and other underrepresented students in the College of Engineering by offering the Software Engineering graduate degrees. Additional features and programs that contribute to enhancing student success and increasing diversity and inclusion will also be included in the support infrastructure for the degree.

IV. Projected Enrollment for the First Five Years:

The planned start date for the PhD program in Software Engineering is Fall 2023. The projected enrollment in the program is shown in the table below *(note that it was extended out to a 5-year projection)*. The basis for these projections was derived by comparing enrollments at other Arizona and AAU universities that have a similar Software Engineering graduate programs.

Degree	Year 1 (2023 / 2024)	Year 2 (2024 / 2025)	Year 3 (2025 / 2026)	Year 4 (2026 / 2027)	Year 5 (2027 / 2028)
PhD	4	8	12	20	30

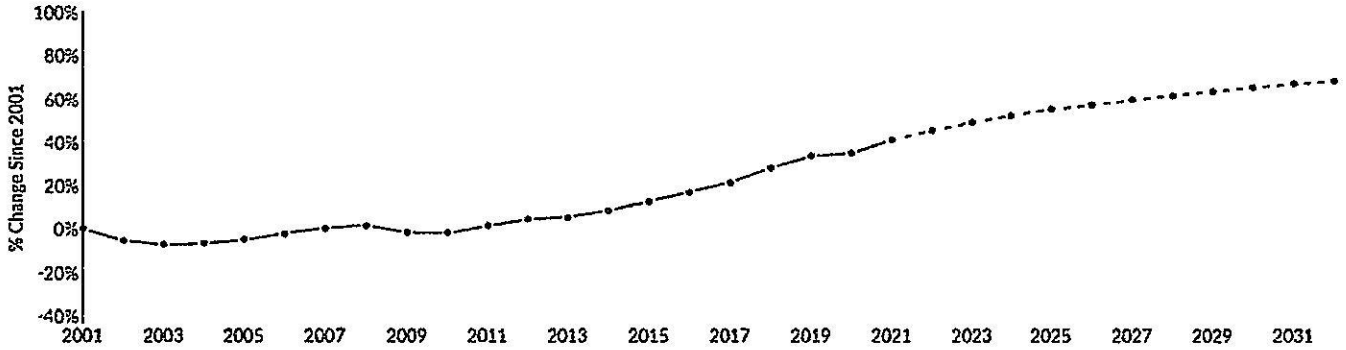
V. **Evidence of Market Demand:**

The market demand for those trained in engineering computing /software engineering disciplines (CIP code 14.093 - Computer Software Engineering) is projected to have significant growth in both the near-term and long-term future. As shown in the diagram below, sourced from Lightcast Q3 2022 data[1], the number of regional[2] jobs in the workforce with a MS or PhD or other professional degree is expected to see a 11.3% increase over 5 years, between 2021 – 2026 (and continues to increase at a similar rate through at least 2031).

[1] Lightcast Q3 2022 Data Set, www.economicmodeling.com

[2] Regional jobs include the states located in the southwest region of the United States

Regional Trends



Region	2021 Jobs	2026 Jobs	Change	% Change
• Region	3,074,978	3,421,626	346,648	11.3%

Thus, the new SFWE PhD degree program 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[3].

The full marketing and analysis report can be found at the following link:
https://arizona.box.com/s/g2sm18hc6gwxi5th7fch49vnau4etsrb

[3] World Economic Forum. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

VI. **Similar Programs Offered at Arizona Public Universities:**

University	Program	College
University of Arizona	BS Software Engineering	College of Engineering
University of Arizona	MS Computer Science PhD Computer Science	College of Science
Arizona State University	MS Software Engineering	School of Computing and Augmented Intelligence, IRA A Fulton Schools of Engineering
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

VII. **Resources**

a. The table below summarizes the projected new resources required to offer the program:

Resources	Quantity
Faculty	2
Staff	0
Other (TAs, Graders, LAs) *(Semester hires over 5 years)*	0 TAs *(total # semester hires over 5 years, averaging 3.5 TAs/year)* 0 Graders 0 LAs
Equipment	None
Facilities	Office and lab space *(for new faculty)*

b. Estimate total expected cost: $1,206,817 *(extrapolated over 5 years)*

c. Estimate total expected revenue of the program: $797,980 *(extrapolated over 5 years)*

VIII. **Required Signatures**

a. ~~**Graduate Studies Committee Chair**~~ **/ Main Proposer:**

i. **Signature:** _____

ii. **Name and Title:** ~~Dr Vignesh Subbian, Chair SIE Graduate Studies Committee~~ Director, Software Engineering

iii. **Date:** 10/21/2022

b. **Managing Unit/Department Head:**

i. **Signature:** Ricardo Valerdi

ii. **Name and Title:** Dr Ricardo Valerdi, Systems and Industrial Engineering (SIE) Dept Head

iii. **Date:** 10/21/2022

c. **Managing Unit/Department Head:**

i. **Signature:** _____

ii. **Name and Title:** Dr Michael Wu, Electrical and Computer Engineering (ECE) Dept Head

iii. **Date:** 10/21/2022

d. **College Dean/Associate Dean:**

i. **Signature:** _____

ii. **Name and Title:** Dr David Hahn, Dean College of Engineering

iii. **Date:** 10/21/2022

THE UNIVERSITY OF ARIZONA

ACADEMIC ADMINISTRATION
Administration Building, 402
1401 E. University Blvd.
PO Box 210066
Tucson, AZ 85721-0066

To: David Hahn, Dean, College of Engineering
Ricardo Valerdi, Department Head, Systems and Industrial Engineering (SIE), College of Engineering
Michael Wu, Department Head, Electrical and Computer Engineering (ECE), College of Engineering
Sharon O'Neal, Director, Software Engineering Program, College of Engineering

From: Greg Heileman, PhD, Vice Provost for Undergraduate Education

Date: November 28, 2022

Subject: Approval of Preliminary Proposal for MS and PhD in Software Engineering

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Thank you for submitting the preliminary proposal for a MS and PhD in Software Engineering. The proposed academic programs should provide an excellent educational opportunity and useful degrees for students. We believe your ideas are sufficiently well developed that it now makes sense to advance through the stages of the formal academic program approval process.

Please proceed to the development of a full proposal, and do not hesitate to reach out the Curricular Affairs Office for assistance with this process.

CC: Liesl Folks, Senior Vice President for Academic Affairs and Provost
Liz Sandoval, Director, Curricular Affairs

THE UNIVERSITY OF ARIZONA

ACADEMIC PROGRAM – ADDITIONAL INFORMATION FORM

To be used once the preliminary proposal has been approved.

I. MAJOR REQUIREMENTS - Doctor of Philosophy (PhD) – Software Engineering

Total units required to complete the degree	63
Pre-admissions expectations (i.e., academic training to be completed prior to admission)	Applicants interested in pursuing a PhD must meet the following minimum requirements: • A minimum 3.0 cumulative GPA in their overall undergraduate degree or meet Graduate College minimum admissions requirements. • Hold a BS degree in math, physics, chemistry, or engineering or related field. Students with BS degrees in disciplines not directly related to Software Engineering may be admitted into the MS or PhD program. PhD students who do not have a BS in Software Engineering must demonstrate competency in any prerequisite courses to graduate level software engineering courses. Students may take pre-requisite and co-requisite courses for audit or credit, or students learn the material from these courses on their own time to successfully pass the required prerequisites. The following are suggestions for PhD students to satisfy prerequisites: 1. Provide proof (transcript and a description of the course) of satisfactorily completing equivalent coursework at an institution recognized by the University of Arizona. 2. Receive course credit by examination (consult with the Graduate Studies Committee) if allowed. The SFWE doctoral program does not require applicants to have an MS degree to be admitted. Admitted PhD students have the option to earn a SFWE MS degree enroute to their PhD.
Major requirements. List all major requirements including core and electives. If applicable, list the emphasis requirements for each proposed emphasis*. Courses listed must include course	<u>Required Core Courses (15 units):</u> • SFWE 513 (3) – Software Engineering Research Methods (NEW)

prefix, number, units, and title. Mark new coursework (New). Include any limits/restrictions needed (house number limit, etc.). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.	• SFWE 507 (3) – Foundations of Software Engineering (NEW)
	
	• Complete 9 units of additional core coursework:
	  ○ SFWE 502 (3) - Software DevSecOps
	  ○ SFWE 503 (3) - Software Project Management
	  ○ SFWE 504 (3) - Software Requirements Analysis and Test (NEW)
	  ○ SFWE 505 (3) - Software Architecture and Design (NEW)
	  ○ SFWE 506 (3) - Distributed Computing (NEW)
	
	Students that have a BS in Software Engineering and have demonstrated a given Core course's competencies ***must*** consult/work with their faculty advisor to substitute the course with one of the SFWE 5xx level courses listed below.
	
	• Choose 16 units non-dissertation course work which must be approved by the faculty advisor and the Director of Graduate Studies:
	
	  ○ Any SFWE core courses not used to meet the *Core* coursework requirement can also be used as technical electives
	  ○ SFWE 501 (3) - SW Assurance
	  ○ SFWE 508 (3) –Data Mining (NEW)
	  ○ SFWE 509 (3) – Cloud Computing Principles and Practices (NEW)
	  ○ SFWE 510 (3) – Cloud Native Software Engineering (NEW)
	  ○ SFWE 511 (3) – Software for Industrial Control Systems (NEW)
	  ○ SFWE 512 (3) –Robotics (NEW)
	  ○ SFWE 513 (3) – Software Engineering Research Methods (NEW)
	  ○ CSE 501 (3) – Operating Systems
	  ○ ECE 503 (3) - Probability and Random Processes for Engineering Applications
	  ○ ECE 509 (3) –Cybersecurity Concept, Theory, Practice
	  ○ ECE 513 (3) –Web Development and the IoT
	  ○ ECE 523 (3) –Engineering Applications of Machine Learning and Data Analytics
	  ○ ECE 562 (3) –Computer Architecture and Design
	  ○ ECE 576A (3) - Engineering of Computer Based Systems

	○ ECE 576B (3) - Embedded System Design and Optimization ○ ECE 579 (3) –Principles of Artificial Intelligence ○ SIE 533 (3) –Fundamentals of Data Science for Engineers ○ SIE 558 (3) –Model Based Systems Engineering ○ SIE 577 (3) – Introduction to Biomedical Informatics ○ *Other courses may be added at the discretion of the faculty advisor and GSC, or as additional new SFWE courses not listed in section **III. New Courses Needed** are developed.* <u>Minor Courses (12 units):</u> • All minor coursework (12 units) can come from a single discipline or split between two disciplines (6 units from each discipline). <u>Colloquium and Dissertation Research (20 units)</u> • SFWE 695A - Colloquium (2) • SFWE 920 - Dissertation Research (18)
Research methods, data analysis, and methodology requirements (Yes/No). If yes, provide description.	• SFWE 513 – Software Engineering Research Methods • SFWE 920 - Dissertation Research
Internship, practicum, applied course requirements (Yes/No). If yes, provide description.	None
Master thesis or dissertation required (Yes/No). If yes, provide description.	If the student selects the MS *Thesis Option*, they are required to complete 6 units of research in an area related to software engineering. The thesis will capture the results of the research that was completed under the guidance of a faculty member. The thesis paper should demonstrate the students core knowledge, technical skills, and the ability to articulate and synthesize the findings of a project they were engaged in over multiple semesters. Students must pass an oral defense of their MS thesis. PhD students are also required to complete a dissertation and pass an oral defense of the dissertation.
Additional requirements (provide description)	*Specific requirements will be included in the SFWE Graduate Handbook.*

	Doctoral Qualifying Exam (DQE) - The purpose of the Doctoral Qualifying Examination (DQE) is to assess students' fundamental knowledge in specific SFWE domains and whether students have an integrated understanding in those domains as well as their readiness of a student to undertake advanced graduate work. *Doctoral Comprehensive Exam* - The purpose of the DQE is to determine whether the student has developed sufficient background and expertise for research in the field of their planned dissertation. Successful completion of the examination leads to formal admission to PhD candidacy. *Doctoral Final Written Dissertation* - The candidate should develop a written document that demonstrates all aspects of their research including significance of the 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. Note: The faculty advisor defines the specific format of the written dissertation. The Graduate College provides general formatting guidelines: https://grad.arizona.edu/gsas/dissertations-theses/dissertation-and-thesisformatting-guides *Final Oral Defense* - 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. The exact time and place of the oral defense must be announced publicly at least two weeks in advance of the oral defense. The 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.
Minor options (as relevant)	Minor – required outside of research as specified above.

*Emphases are officially recognized sub-specializations within the discipline. ABOR Policy 2-221 c. Academic Degree Programs Sub specializations requires all undergraduate emphases within a major to share at least 40% curricular commonality across emphases (known

as "major core"). Total units required for each emphasis must be equal. Proposed emphases having similar curriculum with other plans (within department, college, or university) may require completion of an additional comparison chart. Complete the table found in Appendix B to indicate if emphases should be printed on student transcripts and diplomas.

II. **CURRENT COURSES**–using the table below, list all existing courses included in the proposed major. You can find information to complete the table using the UA course catalog or UAnalytics (Catalog and Schedule Dashboard> "Printable Course Descriptions by Department" On Demand Report; right side of screen).

Course prefix and number (include cross-listings)	Units	Title	Pre-requisites	Modes of delivery (online, in-person, hybrid)	Typically Offered (F, W, Sp, Su)	Dept signed party to proposal? (Yes/No)
ECE 509	3	Cybersecurity Concept, Theory, Practice	ECE 578	In-person	Sp	Yes
ECE 513	3	Web Development and the IoT	ECE 275 (or equivalent)	In-person	F	Yes
ECE 503	3	Probability and Random Processes for Engineering Applications	Undergraduate course in Probability	In-person	F	Yes
ECE 523	3	Engineering Applications of Machine Learning and Data Analytics	ECE 503 or equivalent	In-person	Sp	Yes
ECE 562	3	Computer Architecture and Design	ECE 369A (or consent of instructor)	In-person	Sp	Yes
ECE 576A	3	Engineering of Computer Based Systems	ECE 579	In-person	F	Yes
ECE 576B	3	Embedded System Design and Optimization	ECE 576A	In-person	Sp	Yes

ECE 579	3	Principles of Artificial Intelligence	ECE 373 (or equivalent)	In-person	Sp	Yes
SIE 533	3	Fundamentals of Data Science for Engineers	SIE 530 or SIE 500A (or consent of instructor)	In-person, online	F	Yes
SIE 558	3	Model Based Systems Engineering	SIE 554A (or consent of instructor)	In-person, online	F	Yes
SIE 577	3	Introduction to Biomedical Informatics	None	In-person, online	F	Yes
SFWE 501	3	Software Assurance (co-convened with SFWE 401) (updated to include graduate level requirements)	CSE 201, ECE 275 or consent of instructor	In-person, online	Sp	Yes
SFWE 502	3	Software DevSecOps (co-convened with SFWE 402) (updated to include graduate level requirements)	CSE 201, ECE 275 or consent of instructor	In-person, online	F	Yes
SFWE 503	3	Software Project Management (co-convened with SFWE 403) (updated to include graduate level requirements)	Consent of instructor	In-person, online	F	Yes

III. **NEW COURSES NEEDED** – using the table below, list any new courses that must be created for the proposed program. If the specific course number is undetermined, please provide level (i.e., CHEM 4XX). Add rows as needed.

Course prefix and number (include cross-listings)	Units	Title	Pre-requisites	Modes of delivery (online, in-person, hybrid)	Status*	Anticipated first term offered	Typically Offered (F, W, Sp, Su)	Dept signed party to proposal? (Yes/No)	Faculty members available to teach the courses
SFWE 507	3	Foundations of Software Engineering	ECE 275 (or equivalent)	In-person, online	D	Fall 2023	F, Sp	Yes	Dr Mohammad Abu Matar
SFWE 504	3	Software Requirements Analysis and Test	SFWE 507 (recommended) (or consent of instructor)	In-person, online	D	Spring 2024	Sp,	Yes	Sharon ONeal
SFWE 505	3	Software Architecture and Design	SFWE 507 (recommended) (or consent of instructor)	In-person, online	D	Fall 2024	F	Yes	Dr Mohammad Abu Matar
SFWE 506	3	Distributed Computing	SFWE 507 (recommended) (or consent of instructor)	In-person, online	D	Spring 2025	Sp	Yes	Sharon ONeal
SFWE 508	3	Data Mining	ECE 275 (or equivalent)	In-person, online	D	Spring 2025	F	Yes	TBR (New Faculty)
SFWE 509	3	Cloud Computing Principles and Practices	SFWE 507 (recommended) (or consent of instructor)	In-person, online	D	Spring 2024	F	Yes	Dr Mohammad Abu Matar

SFWE 510	3	Cloud Native Software Engineering	SFWE 507 (recommended) (or consent of instructor)	In-person, online	D	Fall 2024	Sp	Yes	TBR (New Faculty)
SFWE 511	3	Software for Industrial Control Systems	ECE 275 (or equivalent)	In-person, online	D	Fall 2023	F	Yes	Dr Pratik Satam
SFWE 512	3	Robotics	ECE 275 (or equivalent)	In-person, online	D	Fall 2025	Sp	Yes	TBR (New Faculty)
SFWE 513	3	Software Engineering Research Methods	None	In-person, online	D	Fall 2024	F	Yes	Dr Pratik Satam
SFWE 910	6	Thesis	Thesis Option	In-person, online	D	Fall 2024	F, Sp	Yes	Varying
SFWE 920	18	Dissertation Research	Doctoral Comprehensive Exam	In-person, online	D	Fall 2024	F, Sp	Yes	Varying

*In development (D); submitted for approval (S); approved (A)

Click or tap here to enter text.

IV. **FACULTY INFORMATION-** complete the table below. If UA Vitae link is not provided/available, add CVs to a Box folder and provide that link. UA Vitae profiles can be found in the UA directory/phonebook. Add rows as needed. **NOTE: full proposals are distributed campus-wide, posted on committee agendas and should be considered "publicly visible". Contact Office of Curricular Affairs if you have concerns about CV information being "publicly visible".**

Faculty Member	Involvement	UA Vitae link or Box folder link
Sharon ONeal	Teach SFWE 503, SFWE 504 and SFWE 506	Sharon L ONeal | UA Profiles (arizona.edu)
Dr Mohammad Abu Matar	Teach SFWE 507 and SFWE 509 (Technical Elective)	https://arizona.box.com/s/7trdpezytljufs2b1bn8fzgawtq8k46g

Dr Pratik Satam	Teach SFWE 501 and SFWE 511 (Technical Electives) and conduct/collaborate in SFWE related research	https://arizona.box.com/s/k41xa25zolvk5qfw0qj5lni0d4a4e3ao
Dr Ravi Tandon	Teach ECE 503 (Technical Elective) and conduct/collaborate in SFWE related research	https://profiles.arizona.edu/person/tandonr
Dr Tosiron Adegbija	Teach ECE 562 (Technical Elective) and conduct/collaborate in SFWE related research	Tosiron Adegbija | UA Profiles (arizona.edu)
Dr Abhijit Mahalanobis	Teach ECE 523 (Technical Elective) and conduct/collaborate in SFWE related research	https://arizona.box.com/s/eximdtrp92tutik04yrfclbyyzj1zidh
Dr Loukas Lazos	Teach ECE 578 (Technical Elective and conduct/collaborate in SFWE related research	Loukas Lazos | UA Profiles (arizona.edu)
Dr Salim Hariri	Teach ECE 509 (Technical Elective) and conduct/collaborate in SFWE related research	Salim A Hariri | UA Profiles (arizona.edu)
Dr Soheil Salehi Mobarakeh	Teach ECE 513 (Technical Elective) and conduct/collaborate in SFWE related research	Soheil Salehi | UA Profiles (arizona.edu)
Dr Michael Marefat	Teach ECE 579 (Technical Elective) and conduct/collaborate in SFWE related research	Michael M. Marefat | UA Profiles (arizona.edu)
Dr Jerzy Rozenblit	Teach ECE 576 A and 576B Conduct/collaborate in CSE related research	https://profiles.arizona.edu/person/jerzyr
Dr Jian Liu	Teach SIE 533 (Technical Elective) and conduct/collaborate in SFWE related research	Jian Liu | UA Profiles (arizona.edu)
Dr Vignesh Subbian	Teach SIE 578 (Technical Elective) and conduct/collaborate in SFWE related research	Vignesh Subbian | UA Profiles (arizona.edu)

Frederick Steiner	Teach SIE 558 (Technical Elective)	Rick Steiner | UA Profiles (arizona.edu)
Dr Ricardo Valerdi	Conduct/collaborate in SFWE related research	https://profiles.arizona.edu/person/rvalerdi

V. GRADUATION PLAN – provide a sample degree plan, based on your program that includes all requirements to graduate with this major and takes into consideration course offerings and sequencing.

The table below represents a sample PhD SFWE degree plan. Because of the flexibility in this degree program, the degree plan of an individual student may differ from what is shown. Each student will develop a tailored degree plan with the SFWE graduate advisor and faculty advisor. The student's degree plan will then be approved by the student's faculty advisor and/or the Graduate Studies Committee (GSC).

Most PhD students will complete their coursework within 4-5 years, although some students may take longer. Typically, the first 5 semesters are close to full time study, and the remaining semesters are spent preparing for and conducting research, taking comprehensive exams, preparing and defending dissertations. Any additional semesters that a student may take passed Semester 8 are typically focused on finalizing their research and dissertation. These are not explicitly shown in the table below, but culminates in 18 units of Dissertation, totaling 63 total units.

Semester 1		Semester 2		Semester 3		Semester 4	
Course prefix and number	Units	Course prefix and number	Units	Course prefix and number	Units	Course prefix and number	Units
SFWE 507	3	SFWE 502, 503, 504, 505, 506	3	SFWE 502, 503, 504, 505, 506	3	Technical Elective	3
Technical Elective	3	Technical Elective	3	SFWE 513	3	Technical Elective	3
SFWE 502, 503, 504, 505, 506	3	Technical Elective	3	Technical Elective	1	Minor Elective	3
-	-	-	-	Doctoral Qualifying Exam	-	-	-
Total	9	Total	9	Total	7	Total	9

Semester 5		Semester 6		Semester 7		Semester 8	
Course prefix and number	Units	Course prefix and number	Units	Course prefix and number	Units	Course prefix and number	Units
Minor Elective	3	SFWE 695A	2	Dissertation (spread over several semesters)	-	Dissertation (spread over several semesters)	18
Minor Elective	3	Written and Oral Comprehensive Exams	-				
Minor Elective	3						
Total	9	Total	2	Total	-	Total	18

VI. **Curriculum Map and Assessment Map** - Complete this table as a summary of your learning outcomes and assessment plan, using these examples as a model. If you need assistance completing this table and/or the Curriculum Map, please contact the Office of Instruction and Assessment. Attach your Curriculum Map here.

Program: PhD Software Engineering

Learning Outcome #1: Demonstrate broad knowledge in the student's field in software engineering.
Concepts: Students will study and research diverse topics in software engineering including software engineering fundamentals, software development and security operations (SW DevSecOps), software requirements analysis and test, software architecture and design, distributed computing, data mining, cloud computing, software for industrial control systems, robotics and a variety of other computing topics that vary based on the electives the student opts to take.
Competencies: Students will demonstrate the ability to design, develop, test, integrate and evaluate software applications/products/systems in diverse computing and engineering domains. Students will also apply their acquired knowledge in these areas to conduct original and novel research in state-of the-art and advanced software engineering principles, processes, and methodologies to meet the requirements/needs of diverse engineering applications.
Assessment Methods: For every new 5xx / 6xx SFWE 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 SIE/ECE Graduate Studies Committee (GSC)s, 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 software engineering 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 software engineering knowledge. Additionally, the student's score on the Doctoral Qualifying Exam (DQE) is used to assess the student's fundamental knowledge in specific SFWE 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.
Learning Outcome #2: Critically analyze and review published research results and other literature related to the student's area of study.
Concepts: Students will learn various research techniques to interpret methods used and results from software related research papers, journals, presentations, and projects. 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 numerous resources and learn to develop strategies for acquiring and using technical references from a variety of sources.
Competencies: Students will demonstrate their ability to read and interpret various forms of software research information, papers, conference proceedings, and data collected to support the research. Students will also demonstrate their understanding of techniques used to write technical papers and journal articles. Students will also be able to explain and analyze research approaches taken and results included in published software engineering research papers, journals and conference proceedings.
Assessment Methods: This outcome will be assessed in software engineering 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 be assessed via the written Doctoral Comprehensive Exam which includes a dissertation proposal related to the students SFWE 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 SFWE 513, 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 software engineering application area/field.
Concepts: Students will utilize their acquired knowledge and new research strategies to conduct novel research in a software engineering field of specialization. Students will meet regularly with their faculty advisor and others within the ECE / SIE departments 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: Students will demonstrate their ability to articulate all aspects of the research in a software 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 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 software engineering 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: Students will utilize their acquired software engineering 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 general questions related to their work.
Competencies: Students will demonstrate their ability to articulate all aspects of the research in a software 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 SIE and/or ECE departments 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 software engineering theory and methods, and (c) interpret and communicate research ideas and findings.

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

PhD Software Engineering

Courses and Activities Mapped to PhD Software Engineering

	Outcome			
	SLO 1 Demonstrate broad knowledge in the student's field in software 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 software engineering 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				
SFWE 507 Foundations of Software Engineering (Required)	IPA			IPA
SFWE 920 Dissertation Research (Required)	P/A	P/A	P/A	P/A
SFWE 513 Software Engineering Research Methods (Required)	P/A	IPA	I	IPA
SFWE 502 Software DevSecOps (Core Elective)	P/A			P/A
SFWE 503 Software Project Management (Core Elective)	P/A			IPA
SFWE 504 Software Requirements Analysis and Test (Core Elective)	P/A			P/A
SFWE 505 Software Architecture and Design (Core Elective)	P/A			P/A
SFWE 506 Distributed Computing (Core Elective)	P/A			
SFWE 508 Data Mining (Core Elective)	P/A			
SFWE 509 Cloud Computing Principles and Practices (Technical Elective)	P/A			
SFWE 510 Cloud Native Software Engineering (Technical Elective)	P/A			
SFWE 511 Software for Industrial Control Systems (Technical Elective)	P/A			
SFWE 512 Robotics (Technical Elective)	P/A			
Exit Survey Exit survey (Indirect)	A	A	A	A

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

VII. **PROGRAM ASSESSMENT PLAN-** using the table below, provide a schedule for program evaluation 1) while students are in the program and 2) after completion of the major. Add rows as needed. Delete EXAMPLE rows.

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 SFWE 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
Academic Program Review	APR Reviewer evaluation responses	Minimum of every 7 years
Data from continuous improvement implementation efforts (recommended by the Graduate Studies Committee (GSC))	Assessment data	At the end of an academic year

VIII. **ANTICIPATED STUDENT ENROLLMENT**-complete the table below. What concrete evidence/data was used to arrive at the numbers?

5-YEAR PROJECTED ANNUAL ENROLLMENT					
	1st Year	2nd Year	3rd Year	4th Year	5th Year
Number of Students					
PhD Degree	4	8	12	20	30

Data/evidence used to determine projected enrollment numbers:

Several regional and/or AAU universities with MS and PhD Software Engineering programs were canvassed for program enrollment. The table that follows shows the total enrollment in some of these programs[1]:

University	PhD Software Engineering Student Enrollment (2020)
University of Michigan - Dearborn	17 (CS inside Engineering)
Carnegie Mellon	Data not available
University of California – Irvine	20

[1] Enrollments derived from https://shinyapps.asee.org/apps/Profiles/

IX. **ANTICIPATED DEGREES AWARDED**- complete the table below, beginning with the first year in which degrees will be awarded. How did you arrive at these numbers? Take into consideration departmental retention rates. Use National Center for Education Statistics College Navigator to find program completion information of peer institutions offering the same or a similar program.

PROJECTED DEGREES AWARDED ANNUALLY					
	1st Year	2nd Year	3rd Year	4th Year	5th Year
Number of Degrees	0	0	0	5	10

Data/evidence used to determine number of anticipated degrees awarded annually:

The estimates in the table above are based on the projected total enrollments over the first 5 years of the program, which includes potential student transfers into the program in the earlier years of the program. Students are expected to graduate as soon as the second year of the program.

Additionally, an analysis of other university graduation rates in similar programs was performed as defined in the National Center for Education Statistics[2] (also included numbers from ASEE[3]). In particular, the universities considered are shown in the table below:

University	Number of PhD Awards Conferred in either 2019-2020 or 2020-2021	ASEE Number of PhD Awards Conferred in 2019 and 2020
University of Michigan	Data Not Available	32 / 32
Carnegie Mellon	4	Data not available
University of California – Irvine	0	2 / 4

X. **PROGRAM DEVELOPMENT TIMELINE-** describe plans and timelines for 1) marketing the major and 2) student recruitment activities.

The graduate level programs in Software Engineering utilize several existing courses within the College of Engineering, including:

[2] https://nces.ed.gov/collegenavigator/
[3] https://shinyapps.asee.org/apps/Profiles/

- Electrical and Computer Engineering (ECE) Department
- Systems and Industrial Engineering (SIE) Dept
- Software Engineering (SFWE) program (which is co-owned by ECE and SIE)

The table below shows the preliminary plan for the new PhD Software Engineering course development required for the program *(note: that a separate proposal is being submitted at the same time as the PhD program proposal and these courses are shared between both programs)*. We will work closely with UArizona's University Center for Assessment, Teaching and Technology (UCATT) and UA Online to execute the plan shown in the table below.

Course Number / Name	Planned Development Timeframe	First Semester Offered
SFWE 507 - Foundations of Software Engineering	Fall 2023	Spring 2024
SFWE 504 - Software Requirements Analysis and Test	Fall 2023	Spring 2024
SFWE 505 - Software Architecture and Design	Spring 2024	Fall 2024
SFWE 506 - Distributed Computing	Fall 2024	Spring 2025
SFWE 508 - Data Mining	Fall 2024	Spring 2025
SFWE 509 - Cloud Computing Principles and Practices	Fall 2023	Spring 2024
SFWE 510 - Cloud Native Software Engineering	Spring 2024	Fall 2024
SFWE 511 - Software for Industrial Control Systems	Spring 2024	Fall 2024
SFWE 512 - Robotics	Spring 2025	Fall 2025
SFWE 513 – Research Methods	Spring 2024	Fall 2024
SFWE 910 - Thesis	Spring 2024	Fall 2024
SFWE 920 – Dissertation Research	Spring 2025	Fall 2026

We will also work closely with the recruitment and marketing teams (MarCom) within the College of Engineering to market the program as soon as ABOR approves the degree program. Additionally, we will also work closely with Arizona Online to market the program through their marketing channels.

IX. **Program Fees and Differential Tuition (PFDT) Request** – For implementation of fees, you must work with University Fees. The annual deadline is December 1. For any questions, please contact the University Fees Program Manager.

None planned for this program.

Appendix B. Emphasis Print Information-if applicable, complete the table below to indicate if proposed emphases should be printed on transcript and diploma. Add rows as needed. Note: emphases are displayed on transcript and diplomas as " _____ Emphasis".

Emphasis	Print on transcript	Print on diploma
Not Applicable	N/A	N/A

THE UNIVERSITY OF ARIZONA

ACADEMIC PROGRAM – ADDITIONAL INFORMATION FORM

To be used once the preliminary proposal has been approved.

Appendix C. ABOR Form

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: *University of Arizona*

Name of Proposed Academic Program: PhD Software Engineering (SFWE)
Academic Department: College of Engineering: 2303 - Electrical and Computer Engineering (50%) 2302 - Systems and Industrial Engineering (50%)
Geographic Site: Tucson-Main and UArizona Online
Instructional Modality: In-person Online / ONLN (Note: there may be iCourses and/or hybrid courses offered to complement the In-person and Online modalities.)
Total Credit Hours: 63 units
Proposed Inception Term: Fall 2023
Brief Program Description: The PhD Software Engineering curriculum applies software engineering fundamentals to develop and produce computing-based products/solutions. The MS SFWE program is grounded in solid engineering practices and principles governed by the IEEE Software Engineering Body of Knowledge (IEEE SWEBOK). IEEE SWEBOK recommends specific skills that all software engineers should possess regardless of their programming languages and platforms. Our curriculum focuses on the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software. The PhD curriculum also builds upon the MS

Software Engineering program by adding additional coursework and research opportunities for students wishing to pursue a PhD in Software Engineering.

The PhD SFWE 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 in areas that emphasize software engineering, communication, teamwork, critical thinking, and engineering professionalism. In the PhD program, students will also conduct novel research in many diverse software engineering related areas. The program's flexibility allows students to design their course of study / research from a diverse pool of courses and research opportunities in software and computer engineering domains such as web and mobile applications, embedded systems, cybersecurity, machine learning, systems, and other interdisciplinary areas.

Learning Outcomes and Assessment Plan:

The learning outcomes are described in the table below:

Learning Outcome #1: Demonstrate broad knowledge in the student's field in software engineering.
Concepts: Students will study and research diverse topics in software engineering including software engineering fundamentals, software development and security operations (SW DevSecOps), software requirements analysis and test, software architecture and design, distributed computing, data mining, cloud computing, software for industrial control systems, robotics and a variety of other computing topics that vary based on the electives the student opts to take.
Competencies: Students will demonstrate the ability to design, develop, test, integrate and evaluate software applications/products/systems in diverse computing and engineering domains. Students will also apply their acquired knowledge in these areas to conduct original and novel research in state-of the-art and advanced software engineering principles, processes, and methodologies to meet the requirements/needs of diverse engineering applications.
Assessment Methods: For every new 5xx / 6xx SFWE 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 SIE/ECE Graduate Studies Committee (GSC)s, 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 software engineering 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 software engineering knowledge. Additionally, the student's score on the Doctoral Qualifying Exam (DQE) is used to assess the student's fundamental knowledge in specific SFWE 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.
Learning Outcome #2: Critically analyze and review published research results and other literature related to the student's area of study.	
	Concepts: Students will learn various research techniques to interpret methods used and results from software related research papers, journals, presentations, and projects. 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 numerous resources and learn to develop strategies for acquiring and using technical references from a variety of sources.
	Competencies: Students will demonstrate their ability to read and interpret various forms of software research information, papers, conference proceedings, and data collected to support the research. Students will also demonstrate their understanding of techniques used to write technical papers and journal articles. Students will also be able to explain and analyze research approaches taken and results included in published software engineering research papers, journals and conference proceedings.
	Assessment Methods: This outcome will be assessed in software engineering 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 be assessed via the written Doctoral Comprehensive Exam which includes a

	dissertation proposal related to the students SFWE 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 SFWE 513, 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 software engineering application area/field.	
	Concepts: Students will utilize their acquired knowledge and new research strategies to conduct novel research in a software engineering field of specialization. Students will meet regularly with their faculty advisor and others within the ECE / SIE departments 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: Students will demonstrate their ability to articulate all aspects of the research in a software 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 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 software engineering 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: Students will utilize their acquired software engineering 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 general questions related to their work.
Competencies: Students will demonstrate their ability to articulate all aspects of the research in a software 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 SIE and/or ECE departments 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 software 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 SFWE courses that are part of this program. Existing technical elective courses used to fulfill the degree requirements are not included. The assessment plans for existing courses will be followed per the home department's assessment plan for each respective existing course.

PhD Software Engineering

Courses and Activities Mapped to PhD Software Engineering

	Outcome			
	SLO 1 Demonstrate broad knowledge in the student's field in software 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 software engineering 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				
SFWE 507 Foundations of Software Engineering (Required)	IPA			IPA
SFWE 920 Dissertation Research (Required)	P/A	P/A	P/A	P/A
SFWE 513 Software Engineering Research Methods (Required)	P/A	IPA	I	IPA
SFWE 502 Software DevSecOps (Core Elective)	P/A			P/A
SFWE 503 Software Project Management (Core Elective)	P/A			IPA
SFWE 504 Software Requirements Analysis and Test (Core Elective)	P/A			P/A
SFWE 505 Software Architecture and Design (Core Elective)	P/A			P/A
SFWE 506 Distributed Computing (Core Elective)	P/A			
SFWE 508 Data Mining (Core Elective)	P/A			
SFWE 509 Cloud Computing Principles and Practices (Technical Elective)	P/A			
SFWE 510 Cloud Native Software Engineering (Technical Elective)	P/A			
SFWE 511 Software for Industrial Control Systems (Technical Elective)	P/A			
SFWE 512 Robotics (Technical Elective)	P/A			
Exit Survey Exit survey (Indirect)	A	A	A	A

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

A summary of the assessment measures is shown in the table below:

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 SFWE 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
Academic Program Review	APR Reviewer evaluation responses	Minimum of every 7 years
Data from continuous improvement implementation efforts (recommended by the Graduate Studies Committee (GSC))	Assessment data	At the end of an academic year

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 (2023 / 2024)	Year 2 (2024 / 2025)	Year 3 (2025 / 2026)
PhD	4	8	12

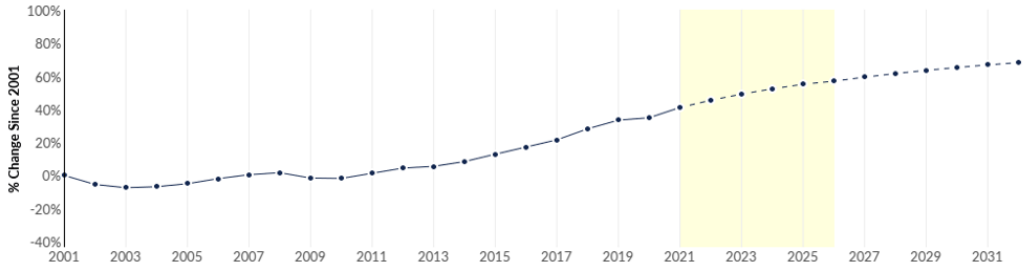
Evidence of Market Demand:

The market demand for those trained in engineering computing /software engineering disciplines (CIP code 14.093 - Computer Software Engineering) is projected to have significant growth in both the near-term and long-term future. As shown in the diagram below, sourced from Lightcast Q3 2022 data[4], the number of regional[5] jobs in the workforce with a MS or PhD or other professional degree is expected to see a 11.3% increase over 5 years, between 2021 - 2026.

[4] Lightcast Q3 2022 Data Set, www.economicmodeling.com

[5] Regional jobs include the states located in the southwest region of the United States

Regional Trends



Region	2021 Jobs	2026 Jobs	Change	% Change
• Region	3,074,978	3,421,626	346,648	11.3%

Thus, the new SFWE 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[6].

The full marketing and analysis report can be found at the following link: https://arizona.box.com/s/g2sm18hc6gwxi5th7fch49vnau4etsrb

Similar Programs Offered at Arizona Public Universities:

University	Program	College
University of Arizona	BS Software Engineering *(Proposal submitted for MS SFWE)*	College of Engineering
University of Arizona	MS Computer Science	College of Science

[6] World Economic Forum. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

	PhD Computer Science	
Arizona State University	MS Software Engineering	School of Computing and Augmented Intelligence, IRA A Fulton Schools of Engineering
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

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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.):

Resources	Quantity
Faculty	2
Staff	1
Other (TAs, Graders, LAs) *(Semester hires over 5 years)*	0 TAs *(total # semester TA hires over 5 years, averaging 3.5 TAs/year)* 0 Graders 0 LAs
Equipment	None
Facilities	Office and lab space *(for new faculty)*

Plan to Request Program Fee/Differentiated Tuition? No

Estimated Amount: N/A

Program Fee Justification:

Note: The fee setting process requires additional steps and forms that need to be completed. Please work with your University Fees office to complete a fee request.

N/A

Specialized Accreditation? No

Accreditor: N/A

Graduate Major Peer Comparison Chart-select two peers for completing the comparison chart from (in order of priority) ABOR-approved institutions, AAU members, and/or other relevant institutions recognized in the field. The comparison chart will be used to identify typically required coursework, themes, and experiences for majors within the discipline. The comparison programs are not required to have the same degree type and/or major name as the proposed UA program. Information for the proposed UA program must be consistent throughout the proposal documents.

Program name, emphasis (sub-plan) name (if applicable), degree, and institution	**Proposed UA Program:** **PhD Software Engineering**	**Peer 1:** **PhD Software Engineering University of California - Irvine** UC IrvineSW Engr	**Peer 2:** **PhD Software Engineering Carnegie Mellon University** **CMU PhD SW Engr**
Current # of enrolled students		20[1]	Not available
Major Description. Includes the purpose, nature, and highlights of the curriculum, faculty expertise, emphases (sub-plans; if any), etc.	The PhD Software Engineering curriculum applies software engineering fundamentals to develop and produce computing-based products/solutions. The PhD SFWE program is grounded in solid engineering practices and principles governed by the IEEE Software Engineering Body of Knowledge (IEEE SWEBOK). IEEE SWEBOK recommends specific skills that all software engineers should possess regardless of their programming languages and platforms. Our curriculum focuses on the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software. The PhD curriculum builds upon the MS Software Engineering program by adding additional coursework and research opportunities for students wishing to pursue a PhD in Software Engineering. Both programs have a firm engineering foundation that encompasses discovery-based education utilizing an experiential learning approach. As a part of both curriculums, students will complete projects in areas that emphasize software engineering, communication, teamwork, critical thinking, and engineering professionalism. The program's flexibility	The software engineering Ph.D. program offers students the opportunity to tackle these challenges, whether it is through designing new tools, performing studies of developers and teams at work, creating new infrastructures or developing new theories about software and how it is developed. No fewer than six faculty members bring a broad range of expertise and perspectives to the program, guaranteeing a diverse yet deep education in the topic. A strong core of classes introduces students to classic material and recent innovations. At the same time, we focus on research from the beginning. New students are required to identify and experiment with one or more research topics early, so that they can become familiar with the nature of research, write	Software is becoming ever more important to our daily lives, as well as every sector of industry. But as software systems increase in capability, they increase in complexity, resulting in delays, defects, and vulnerabilities. Our Ph.D. program in Software Engineering seeks to educate the next generation of high-impact software engineering research, development, and educational leaders who will solve the problems associated with building large-scale and critical software systems. Learn about our groundbreaking research, our world-leading faculty, and our alumni who are already making a big difference in the world.

[1] Enrollments derived from https://shinyapps.asee.org/apps/Profiles/

	allows students to design their course of study / research from a diverse pool of courses and research opportunities in software and computer engineering domains such as web and mobile applications, embedded systems, cybersecurity, machine learning, systems, and other interdisciplinary areas.	papers, attend conferences and begin to become part of the broader software engineering community. This focus on research naturally continues throughout the program, with an emphasis on publishing novel results in the appropriate venues.	
Target careers	• Software researcher • University professor • Software Engineer / Entrepreneur for variety of application areas: - Web - Mobile - Embedded systems - Avionics - Robotics - Other software related fields • Software Project Management / Leadership	• Software researcher • University professor • Software Engineer / Entrepreneur for variety of application areas: - Web - Mobile - Embedded systems - Avionics - Robotics - Other software related fields • Software Project Management / Leadership	• Software researcher • University professor • Software Engineer / Entrepreneur for variety of application areas: - Web - Mobile - Embedded systems - Avionics - Robotics - Other software related fields • Software Project Management / Leadership
Total units required to complete the degree	63	48 units + Dissertation	84 *(Note: Most CMU courses are 12 units)*
Pre-admission expectations (i.e. academic training to be completed prior to admission)	Bachelor's degree from an institution recognized by the UA. Students who do not have a degree equivalent to the UA Bachelor of Science degree in a computing related program may be admitted into the graduate SFWE program but may be required to complete additional graduate-level prerequisite courses prior to enrolling in some graduate courses. • Grade-point average greater than 3.0 overall (or in the last 60 units). • Applicants whose native language is not English are required by the Graduate College to take an English proficiency test. A description of acceptable tests can be found on the Graduate College website. • Students in the MS non-thesis option are expected to be self-supported or supported by external fellowships or industry, and are not eligible for UA financial support, except	• Minimum GPA = 3.0 in last 60 credit hours of undergraduate degree program • Deficiency courses differ depending on undergraduate degree (cannot have more than 2 deficiencies) • GRE scores of 146 verbal, 155 quantitative, and 3.0 analytical writing • English proficiency – TOEFL score of 575	• Qualified students that have earned an undergraduate degree in a relevant field. • GRE optional • Minimum DET composite score of 105 for international students

	for research assistantships provided by individual faculty.		
Major requirements. List all major requirements including core and electives. If applicable, list the emphasis requirements. Courses listed must include course prefix, number, units, and title. Mark new coursework (New). Include any limits/restrictions needed (house number limit, etc.). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.	<u>Required Core Courses (15):</u> • SFWE 513 (3) – Software Engineering Research Methods (NEW) • SFWE 507 (3) – Foundations of Software Engineering (NEW) • Complete 3 courses of additional core coursework: o SFWE 502 (3) - Software DevSecOps o SFWE 503 (3) - Software Project Management o SFWE 504 (3) - Software Requirements Analysis and Test (NEW) o SFWE 505 (3) - Software Architecture and Design (NEW) o SFWE 506 (3) - Distributed Computing (NEW) Students that have a BS in Software Engineering and have demonstrated a given Core course's competencies *must* consult/work with their faculty advisor to substitute the course with one of the SFWE 5xx level courses listed below. • Choose 16 units non-dissertation course work which must be approved by the faculty advisor and the Director of Graduate Studies: o Any SFWE core courses not used to meet the *Core* coursework requirement can also be used as technical electives. o SFWE 501 (3) - SW Assurance o SFWE 508 (3) –Data Mining (NEW) o SFWE 509 (3) – Cloud Computing Principles and Practices (NEW)	• Students must complete a software engineering core course, five elective courses, and at least three quarters of individual study and/or thesis supervision courses. • Students must take additional courses of their own choosing or additional individual studies, in order to fulfill 48 units before advancement to candidacy. • The selection of courses should form a coherent educational plan to be approved by the student's faculty advisor.	The purpose of completing graduate courses at Carnegie Mellon University is to attain a broad understanding of software engineering and closely related fields, a core set of research skills, and a deep understanding of topics that lead into the student's thesis research. Our requirement is that students complete 84 university units, which is the equivalent of 7 standard 12-unit courses. Our core research course, 17-808, provides an understanding of the Software Engineering field, including important ideas and the major research strategies in use. Certain courses are designated as 'star' courses because they provide a solid foundation in some area. By taking a star course in each of the four categories, students acquire breadth through exposure to fundamental knowledge, concepts, and skills in software engineering. Through the equivalent of two elective courses, students typically choose to gain more depth in the student's particular area of research. Some students use electives to gain more breadth by specialized exposure to an area outside of the

	○ SFWE 510 (3) – Cloud Native Software Engineering (NEW) ○ SFWE 511 (3) – Software for Industrial Control Systems (NEW) ○ SFWE 512 (3) –Robotics (NEW) ○ SFWE 513 (3) – Software Engineering Research Methods (NEW) ○ CSE 501 (3) – Operating Systems ○ ECE 503 (3) - Probability and Random Processes for Engineering Applications ○ ECE 509 (3) –Cybersecurity Concept, Theory, Practice ○ ECE 513 (3) –Web Development and the IoT ○ ECE 523 (3) –Engineering Applications of Machine Learning and Data Analytics ○ ECE 562 (3) –Computer Architecture and Design ○ ECE 576A (3) - Engineering of Computer Based Systems ○ ECE 576B (3) - Embedded System Design and Optimization ○ ECE 579 (3) –Principles of Artificial Intelligence ○ SIE 533 (3) –Fundamentals of Data Science for Engineers ○ SIE 558 (3) –Model Based Systems Engineering ○ SIE 577 (3) – Introduction to Biomedical Informatics ○ *Other courses may be added at the discretion of the faculty advisor and GSC, or as additional new SFWE courses not listed in section **III. New Courses Needed** are developed.* <u>Minor Courses (12 units):</u> • All minor coursework (12 units) can come from a single discipline or split between two disciplines (6 units from each discipline).		student's core research area. Students must take: • Software Engineering Research Course (17-808) • 4 Area *Star* courses: • Each student must pass one *Star* course from each of four categories: ○ **SYM**: Symbolic mathematical modeling and analysis ○ **BEH**: Human-focused empirical research ○ **ENG**: Design and engineering of software systems ○ **SOC**: The interaction of software with larger issues in society, business, or public policy. • 24 Elective Units

	<u>Colloquium and Dissertation Research (20 units)</u> • SFWE 695A - Colloquium (2) • SFWE 920 - Dissertation Research (18)		
Research methods, data analysis, and methodology requirements (Yes/No). If yes, provide description.	<u>Colloquium and Dissertation Research (20 units)</u> • SFWE 695A - Colloquium (2) • SFWE 920 - Dissertation Research (18) All PhD students are required to complete a Dissertation and defend their Dissertation (see information in the table below).	Students must find a faculty advisor and successfully complete a research project with that faculty member. The research project should be done over at least two quarters of independent study with that faculty member. The goal of this research assessment is to introduce the student to the practice of scientific publication. Based on the project, the student must produce a research paper of publishable quality. This research paper must be reviewed by three faculty members in a peer-review process, revised by the student, and approved by the three faculty members. The research assessment is graded Ph.D. PASS, M.S. PASS, or FAIL. In case of M.S. PASS or FAIL, the student can re-submit the paper at most one more time within the maximum period of six months. A second M.S. PASS or FAIL results in disqualification from the doctoral program.	• Software Engineering Research Course (17-808)
Internship, practicum, applied course requirements (Yes/No). If yes,	None	None	None

provide description.			
Master thesis or dissertation required (Yes/No). If yes, provide description.	The candidate should develop a written document that demonstrates all aspects of their research including significance of the 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. Note: The faculty advisor defines the specific format of the written dissertation. The Graduate College provides general formatting guidelines: https://grad.arizona.edu/gsas/dissertations-theses/dissertation-and-thesisformatting-guides ***Final Oral Defense*** **-** 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. The exact time and place of the oral defense must be announced publicly at least two weeks in advance of the oral defense. The 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.	**Dissertation Topic Defense** The student must present a carefully articulated document representing the student's dissertation plan. This document must include the proposed dissertation abstract, a discussion of the approach, a comprehensive survey of related work, and a plan for completing the work. The dissertation plan is presented by the student to the dissertation committee, who must unanimously approve the student's proposal. The dissertation defense committee is formed in accordance to UCI Senate regulations. **Doctoral Dissertation and Final Examination** Students are required to complete a doctoral dissertation in accordance with Academic Senate regulations. In addition, they must pass an oral thesis defense which consists of a public presentation of the student's research followed by an oral examination by the student's doctoral committee. The committee must approve the thesis unanimously. The normative time for advancement to candidacy is three years. The normative time for completion of the Ph.D. is six years, and the maximum time permitted is seven years.	Yes **Year Four or Five:** The student completes the dissertation research, writes up the thesis, and defends it publicly. After addressing any concerns and comments the committee may have, all requirements are complete, and the student becomes a Software Engineering PhD.
Additional requirements	Students must maintain a GPA of 3.0 or better.	All Ph.D. students are expected to maintain a minimum GPA of 3.5	• 12 units must be from the School of Computer Science and

(provide description)		throughout the program. Failure to maintain this minimum will result in a recommendation that the student be disqualified. In addition, no grade lower than a B is counted toward satisfying any course requirements.	the other 12 may be from other graduate courses offered by the rest of the university. In general, elective courses must be PhD level (course numbering 700 and above)

*Note: comparison of additional relevant programs may be requested.

THE UNIVERSITY OF ARIZONA

BUDGET PROJECTION FORM

Name of Proposed Program or Unit: Software Engineering PhD

Budget Contact Person:	Projected					
	1st Year 2023- 2024	**2nd Year** 2024 - 2025	**3rd Year** 2025- 2026	**4th Year** 2026- 2027	**5th Year** 2027- 2028	
METRICS						
Net increase in annual college enrollment UG						
Net increase in college SCH UG						
Net increase in annual college enrollment Grad On campus	4	7	10	16	24	
Net increase in college SCH Grad On campus	72	126	180	288	432	18 units per year
Net increase in annual college enrollment Grad Online	-	1	2	4	6	
Net increase in college SCH Grad Online	-	18	36	72	108	18 units per year
Number of enrollments being charged a Program Fee						
New Sponsored Activity (MTDC)						
Number of Faculty FTE						
FUNDING SOURCES						
Continuing Sources						
UG AIB Revenue - enrollment						
UG AIB On Campus Degree						
UG SCH						
Grad AIB Revenue SCH On campus	26,496	46,368	66,240	105,984	158,976	Used average of 368 per SCH
Grad AIB Revenue enrollment On campus	4,036	7,063	10,090	16,144	24,216	Used average of 1009 per enrollment
Grad AIB Revenue SCH Online	-	12,150	24,300	48,600	72,900	Used average of 675 per SCH
Grad AIB Revenue enrollment Online	-	1,109	2,218	4,436	6,654	Used average of 1109 per enrollment
Program Fee Revenue (net of revenue sharing)						
F and A AIB Revenues		-	-	53,333	106,666	
Reallocation from existing College funds (attach description)						
Other Items (attach description)						
Total Continuing	**$ 30,532**	**$ 66,690**	**$ 102,848**	**$ 228,497**	**$ 369,412**	
One-time Sources						
College fund balances						
Institutional Strategic Investment						
Gift Funding						
Other Items (attach description)						
Total One-time	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	
TOTAL SOURCES	**$ 30,532**	**$ 66,690**	**$ 102,848**	**$ 228,497**	**$ 369,412**	
EXPENDITURE ITEMS						
Continuing Expenditures						
Faculty	-	-	-	130,000	263,250	
Other Personnel	-	-	55,000	56,375	57,784	
Employee Related Expense	-	-	17,545	59,454	102,410	
Graduate Assistantships	-	-	-	-	-	
Other Graduate Aid	-	-	-	-	-	
Operations (materials, supplies, phones, etc.)	10,000	10,000	10,000	17,500	17,500	
Additional Space Cost						
Other Items (attach description)						
Total Continuing	**$ 10,000**	**$ 10,000**	**$ 82,545**	**$ 263,329**	**$ 440,944**	
One-time Expenditures						
Construction or Renovation						
Start-up Equipment	-	-	-	133,333	266,666	
Replace Equipment						
Library Resources						
Other Items (attach description)						
Total One-time	**$ -**	**$ -**	**$ -**	**$ 133,333**	**$ 266,666**	
TOTAL EXPENDITURES	**$ 10,000**	**$ 10,000**	**$ 82,545**	**$ 396,662**	**$ 707,610**	
Net Projected Fiscal Effect	**$ 20,532**	**$ 56,690**	**$ 20,303**	**$ (168,164)**	**$ (338,198)**	

This worksheet contains information required to compute the On Campus program offering requirements for additional personnel.

	Year 1	Year 2	Year 3	Year 4	Year 5
Tenured Track Fauclty				130000	130000
ERE				41080	41080
					133250
					42107
Total Salary				**130000**	**263250**
Total ERE				**41470**	**83977**
Staff			55000	56375	57784
ERE			17545	17984	18433
Total Salary			**55000**	**56375**	**57784**
Total ERE			**17545**	**17984**	**18433**
Overall			55000	56375	57784
ERE			17545	59454	102410
Faculty				130000	263250

	Year 1	Year 2	Year 3	Year 4	Year 5
Teaching Assistant	0	0	0	0	0
ERE	0	0	0	0	0
Tuition	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**

Start up	Year 1	Year 2	Year 3	Year 4	Year 5
Year 1 to 3 - 1 faculty				133333	133333
Year 1 to 3 - 2 faculty					133333
Year 1 to 3 - 3 faculty					

Total start up	**0**	**0**	**0**	**133333**	**266666**
F*A (40% return to College)		0	0	53333	106666

Sharon: Corrected number of teaching assitants

Operating Expenses

Category	FY Cost	Explanatory Notes
Dept. Travel	$5,000	Dept travel, student travel awards
Events/Conferences	$0	Dept events, conferences NACADA,
Office Supplies	$0	
Other Operating Expenses	$0	Lab support, visa support, graduation support, phones, equipment
Recruitment	$7,500	Faculty recruitment
Student group support	$5,000	Seminar and Department Visitor
Total	$17,500	

FY23 Undergraduate $/Metric

Metric	On Campus[1]	Summer/ Winter	Online	Distance[2]	Global Direct
$/Degree	$ 3,000		$ 4,000	$ 3,000	$ 500
$/Enrollment	$ 350	$ 350	$ 275	$ 180	$ 100
$/SCH	$ 185	$ 185	$ 250	$ 175	$ 185

FY23 Graduate Metric %s

Metric	On Campus[1]	Summer/ Winter	Online	Distance[2]	Global Direct
Net Tuition Assigned to Enrollment	17.0%	17.0%	17.0%	17.0%	17.0%
Net Tuition Assigned to SCH	68.0%	68.0%	68.0%	68.0%	68.0%
College Grad Activity Revenue Share	85.0%	85.0%	85.0%	85.0%	85.0%
SBA Grad Activity Revenue Share	15.0%	15.0%	15.0%	15.0%	15.0%

F&A Metric %s

Distribution	Distribution %[3]
PI Distribution	2.0%
College/Support Distribution	38.0%
College F&A Activity Revenue Share	40.0%
Research Development Fund	12.1%
SBA F&A Activity Revenue Sharing	47.9%

Local Sources Revenue Sharing %s

Revenue Source	Share %
Program Fees & Differential Tuition	15.0%
MD Net Tuition Revenue	15.0%
Vet Med Net Tuition Revenue	15.0%
Auxiliary/Designated Revenue (ASC)	11.0%

Auxiliary/Designated Expense (ASC)	**2.0%**

1 = Sierra Vista Tuition included with On Campus
2 = Includes Community Campus
3 = Based on 100% F&A Earnings

Software Engineering MS and PhD Projected Enrollments *(all programs)*					
Degree	Year 1 (2023 / 2024)	Year 2 (2024 / 2025)	Year 3 (2025 / 2026)	Year 4 (2026 / 2027)	Year 5 (2027 / 2028)
BS Program	105	180	310	475	525
MS	12	30	50	80	100
MS Online	8	20	50	70	100
PhD	4	7	10	16	24
PhD Online	0	1	2	4	6
Yearly Total	***129***	***238***	***422***	***645***	***755***

multiplied by 2 per Larry Head suggestion
multiplied by 2 per Larry Head suggestion

THE UNIVERSITY OF ARIZONA
Online, Distance & Continuing Education

October 2022

Prof. Sharon ONeal
Professor and Director, Software Engineering
College of Engineering
University of Arizona

Re: MS and PhD Software Engineering online and distance degree programs – Letter of support

Dear Prof. ONeal,

On behalf of the University of Arizona's Online, Distance and Continuing Education (ODCE) division, I am pleased to offer this letter of support for your proposal to offer master's and doctorate degrees in Software Engineering to online and distance students. Increased access to this critical field will provide our students, many of whom are adults with family and job responsibilities and cannot travel to Tucson, a great opportunity to achieve their educational goals.

As the university's in-house full-service enterprise for online and distance education we look forward to collaborating with you. Here is a snapshot of our services and support:

- Online curriculum planning and program development;
- Online course design;
- Marketing, student recruitment, and enrollment management; and,
- Student success coaching for increased retention and graduation.

Our ODCE team will work with you in efforts to help increase diversity, accessibility, and degree completion for students enrolled in these innovative STEM programs.

If you require more information about our support for this proposal, please feel free to contact Caleb Simmons (calebsimmons@arizona.edu), executive director for online education; and/or, Carla Holloway (carlaholloway@arizona.edu), executive director for distance education.

Sincerely,

Craig Wilson, JD, PhD
Vice Provost, Online, Distance and Continuing Education
Professor of Practice, College of Education

THE UNIVERSITY OF ARIZONA.

Systems & Industrial Engineering Department

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Fax: (520) 621-6555
www.sie.arizona.edu

April 25, 2023

To Whom It May Concern,

We the Department Heads of the Systems and Industrial Engineering (Ricardo Valerdi), and Electrical and Computer Engineering (Michael Wu), at the University of Arizona are writing this letter to show our support for the new proposed Software Engineering Ph.D. Program. Through this letter we would also like to highlight the differences (and lack of overlap) between Electrical and Computer Engineering (ECE), Computer Science (CS), and Software Engineering (SFWE) Ph.D. programs.

Software Engineering (SFWE) is an **engineering** discipline, focused on all aspects of software development and production including (but not limited to) software requirements, design, construction, testing, maintenance, dev-ops, security, and assurance. Software Engineering (goes beyond 'code writing') focuses on development, evolution, and construction of large software systems that are highly dependable, efficient, usable, accessible, and maintainable throughout the software's lifecycle.

The proposed SFWE Ph.D. program (like the already approved by ABOR SFWE Master's program) plans to have the following course structure:

- **Required Courses:**
  The SFWE Ph.D. students are required to take at least four required courses including SFWE 507.
  - SFWE 507: Foundations of Software Engineering
  - SFWE 503: Software Project Management
  - SFWE 504: Software Requirements Analysis and Test
  - SFWE 505: Software Architecture and Design
  - SFWE 506: Distributed Computing
- **Pre-Approved Technical Electives:**
  In addition to the required courses, the SFWE Ph.D. students can take courses from a pre-approved list of technical electives. Some of the electives are highlighted below (Refer to the proposal for a more complete list).
  - SFWE 501: SW Assurance
  - SFWE 508: Data Mining
  - SFWE 509: Cloud Computing Principles and Practices
  - SFWE 510: Cloud Native Software Engineering
  - SFWE 511: Software for Industrial Control Systems
  - SFWE 512: Robotics
  - SFWE 513: Software Engineering Research Methods

In addition to these courses, the students are required to take research credits and perform research with their Ph.D. advisors on related research topics.

The Department of Computer Science (CSC) at the University of Arizona is **science** discipline that focuses on theoretical (not engineering) aspects of computation, with focus theoretical disciplines like algorithms, theory of computation, and information theory. The Ph.D. in computer science at University of Arizona focuses on these aspects and has the following course requirements:

- Core Curriculum (selected courses only, refer to the CSC course catalog for complete list):
    - CSC 525: Principles of Computer Networking
    - CSC 552: Advanced Operating Systems
    - CSC 553: Principles of Compilation
    - CSC 576: Computer Architecture
    - CSC 545: Design and Analysis of Algorithms
    - CSC 573: Theory of Computation
    - CSC 520: Principles of programming languages
    - CSC 533: Computer Graphics
    - CSC 588: Machine Learning Theory.

In addition to the core curriculum, the CSC Ph.D. students are required to take elective courses, and perform research under their Ph.D. advisors.

By presenting the CSC Ph.D. program requirements we highlight that there is no overlap between the CSC and SFWE programs. The lack of overlap stems from the fact that one is a *'science'* discipline focused on theoretical domains, while the other is an *'engineering'* discipline. To draw the parallel, this is like the overlap an Electrical Engineer fabricating circuits on a die has with Chemistry.

The Electrical and Computer Engineering (ECE) department at the University of Arizona is a combination of Electrical Engineering and Computer Engineering. Computer Engineering refers to the integration of computer science with electronic engineering. The Ph.D. students in the ECE program at the University of Arizona required to take courses for the following list (selected courses only, refer to the ECE course catalog for the complete list):

- ECE 501B: Advanced Linear Systems theory
- ECE 503: Probability and Random Process for Engineering Applications
- ECE 506: Reconfigurable Computing
- ECE 507: Digital VLSI Systems Design
- ECE 509: Cyber Security- Concept, Theory, and Practice
- ECE 523: Engineering Application of Machine Learning and Data Analytics

In addition to these courses, the students are also required to perform research under their Ph.D. advisors.

By presenting the ECE Ph.D. program requirements, we also highlight that there is no overlap between the ECE and the SFWE program. The lack of overlap between ECE and SFWE stems from the fact that while computer engineering focuses on the integration of computer science with electrical engineering, the SFWE focuses on challenges associated with developing and maintaining software systems throughout the development lifecycle.

We would also like to highlight that Arizona Board of Regents (ABOR) approved the SFWE MS program on April 21st, 2023. The SFWE MS and the proposed SFWE Ph.D. program will be sharing all their courses, thus creation of new SFWE courses will be begin and integrated into the course catalog while the SFWE Ph.D. program goes through its final approval process.

The University of Arizona is classified as 'R1: Very High Research Activity' University, where tenure track/tenured professors are expected to perform high quality and cutting impact research, funded through external research grants, and graduate Ph.D. student. All of these activities are not possible without an approved Ph.D. program.

In summary, the SFWE Ph.D. program has no overlap with the existing Computer Science and Electrical and Computer Engineering Ph.D. programs. Moreover, with the establishment of the SFWE MS and the undergraduate program, it is critical we establish the SFWE Ph.D. program. We unconditionally support the SFWE Ph.D. program.

Please do not hesitate to contact us for more information.

Sincerely,

Dr. Ricardo Valerdi
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April 27, 2023

Letter of Support regarding the PhD program in Software Engineering,

Computer Science is looking forward to working with Software Engineering on their proposed PhD program. We are confident that students in both programs will benefit from this collaboration, including having access to graduate classes in both programs.

Christian Collberg
Department Head (Interim)
Department of Computer Science
University of Arizona