New Academic Program:
MS, MEng, and PhD in Artificial Intelligence

BACKGROUND

Program Proposed Start Date

Winter 2021

Program Description

The College of Engineering (CoE) proposes a new Interdisciplinary Graduate Program in Artificial Intelligence (AI) offering MS, MEng, and PhD degrees and graduate minors. The new program will be jointly administered by the School of Electrical Engineering and Computer Science (EECS) and the CoE**.** The objective of the proposed AI program is to train PhD and master's students in the core topics of AI and offer a large set of electives that gives them opportunities to specialize in different sub-areas and applications of AI. The objectives and expectations of different degrees are described below.

PhD: The PhD degrees are aimed at students who will be taking faculty positions in academia, research positions in industry and government labs, and entrepreneurships for leading start-up companies.

Similar to other CoE programs, the master's degrees will be divided into two types, Master of Science (MS) and Master of Engineering (MEng), where the MS degree will have Thesis and Project options.

MS Thesis: The research-oriented master's students who graduate with a MS with thesis option could get a research position in the industry or continue with a PhD at OSU or elsewhere.

MS Project: The industry-oriented students will do a significant software project under the guidance of an advisor to obtain a MS degree with project option. This is an ideal option for students who aim to get a software development job in the AI industry.

MEng: The MEng degree is also industry oriented, except that it is more focused on course work. Unlike the other MEng degrees at OSU, it requires a capstone project which will give students significant real-world project experience, including working in teams.

Table 1: Credits and requirements by degree.

Requirements	PhD	MS	MEng
Algorithms	4 credits	4 credits	4 credits
Big Ideas in AI	2 credits	2 credits	2 credits
Ethical and social issues in AI	3 credits	3 credits	3 credits
Core AI courses	16 credits	12 credits	12 credits
Non-blanket (approved) courses	16 credits	12 credits	12 credits
Dissertation	36 credits	n/a	n/a
Project or Thesis research credits	n/a	6-9 credits	n/a
Capstone	n/a	n/a	3-6 credits
Total credits required	108 credits	45 credits	45 credits

Graduate Minor: A graduate minor in AI is intended for students in other degree programs to help them acquire skills to apply AI methods in their discipline. The graduate minor requires 15 credits for master's students and 18 credits for PhD students including 12 credits from the designated core AI courses in both cases.

Admissions Requirements: To be admitted to the PhD and master's programs, regardless of their discipline, students must demonstrate their mastery of computer programming and their proficiency in mathematical topics including linear algebra, statistics/probability, and calculus. Their proficiency and skills can be demonstrated in multiple ways including course work, research papers, and work experience. It is expected that the degree will be competitive enough that most students will far exceed these minimal expectations.

Program Context

Artificial Intelligence is the study of intelligent artifacts and the principles behind their design, construction, and analysis. While the intellectual roots of AI go back to ancient Greeks, the more modern development of the field began earnestly in the 1950s with the advent of digital computers and the advances in Computer Science. AI is interdisciplinary by its nature connecting varied fields such as philosophy, psychology, mathematics, computer science and engineering. In the past three decades AI has steadily advanced in multiple directions to become a mature discipline with its own methodology, literature, and technical contributions. AI has become a trillion-dollar industry with applications spanning a wide spectrum including search engines, recommender systems, face recognition, visual object recognition, speech recognition, natural language translation, cybersecurity, self-driving cars, and many others. AI is now indispensable to most industries including manufacturing, healthcare, defense, entertainment, and consumer products. The advances in AI have especially dominated the news in the last 10 years and opened numerous opportunities to improve human welfare which were unimaginable only a few years ago. The rapid and multifarious growth of technology has also raised fears of malfunction, bias and abuse, underlining the social and ethical dimensions of AI.

While AI has been around for more than 60 years and thrived as part of computer science, the center of gravity of AI moved away from core subjects of computer science such as operating systems, computer architecture, programming languages, translators and theory of computation. Its relationship to some other fields outside computer science such as operations research, signal processing, statistics and mathematics has strengthened. Depending on the topic of research, a typical researcher in AI needs to master a variety of relevant subject areas. For example, if the subject matter is computer vision, psychophysics, signal processing, and neuroscience might be relevant. If it is language understanding, then linguistics, mathematical logic, and statistics might be more relevant. Solving many of the world's problems such as climate change, public health or self-driving cars require expertise in multiple disciplines. Thus, an ideal program of study is not closely tied to any particular discipline, and lets students pick subjects that are relevant to their research from different disciplines taught in different departments. The intent of the new interdisciplinary degree program is to allow such flexible curricular paths with minimal entrance requirements while opening opportunities for strong interdisciplinary collaborations needed to address the world's problems.

Oregon State University has a strong AI research program as part of the Computer Science (CS) and Electrical and Computer Engineering (ECE) programs in the School of EECS. Currently EECS has 15 active AI faculty members. These 15 faculty teach eight core AI

graduate courses and do fundamental research in AI.

The College has identified AI as one of its strategic priority areas and has a plan to hire five new faculty members in the next five to six years. In addition, there are at least 13 faculty members in CS, ECE and Robotics programs who teach many courses relevant to AI and do research in AI-related topics. Finally, there are at least 42 other faculty members in the larger OSU community with research and teaching interests that overlap with AI. The AI group is the largest in EECS in terms of the amount of external research funding, the number of students, the number of graduate applicants and the number of faculty members with active research programs. The AI faculty routinely serve on the program committees of archival conferences and the editorial boards of top international journals. Currently the AI sub-discipline of the Computer Science program ranks 25th on www.csrankings.org - the de-facto standard for ranking of graduate schools based on the quantity and quality of publications in top-tiered journals and conferences. This compares favorably with the entire CS program, which ranks 46th. With the planned five new faculty hires, the combined expertise of the faculty in EECS and MIME will allow the delivery of a high-quality program in AI.

Program Purpose/Relationship to University Mission and Strategic Plan

The proposed AI program significantly contributes to the targeted strengths listed in OSU's Strategic Plan 4.0. as shown below.

Innovation in Education, Inclusion, and Collaboration: As discussed before, while AI is historically rooted in the discipline of Computer Science, it is connected to a number of different disciplines ranging from philosophy to biology and from statistics to robotics. The interdisciplinary AI degree seeks to bridge this broad spectrum of disciplines by offering a variety of different paths through the intellectual landscape, while at the same time offering a coherent body of core knowledge that is rooted in a computational perspective and informs the other fields. Thus, the program offers excellent opportunities for innovative education and cross-disciplinary collaboration. One such recent example at OSU was the IGERT program in eco-informatics led by faculty in Geosciences, Computer Science, Ecology, Engineering, and Statistics and supported by the National Science Foundation (NSF) for over a decade. The AI program complements the Robotics program which is housed in the School of MIME in supporting the research at the Collaborative Robotics and Intelligent Systems (CoRIS) Institute. The AI program opens opportunities for several such innovative education programs and interdisciplinary collaborations.

Revolutionary Earth Systems Science: AI supports earth systems research by improving ecological and climate models, enabling evidence-based management of forests, agriculture, fisheries and wildlife, supporting renewable energy management, and advancing technologies that support sustainable cities and infrastructure. The timeline in Figure 1, on the next page, taken from World Economic Forum Agenda of 2018 illustrates some of the 'game changing applications' of AI to improve sustainability and ecosystems ranging from better weather forecasts to fully automated connected transportation.

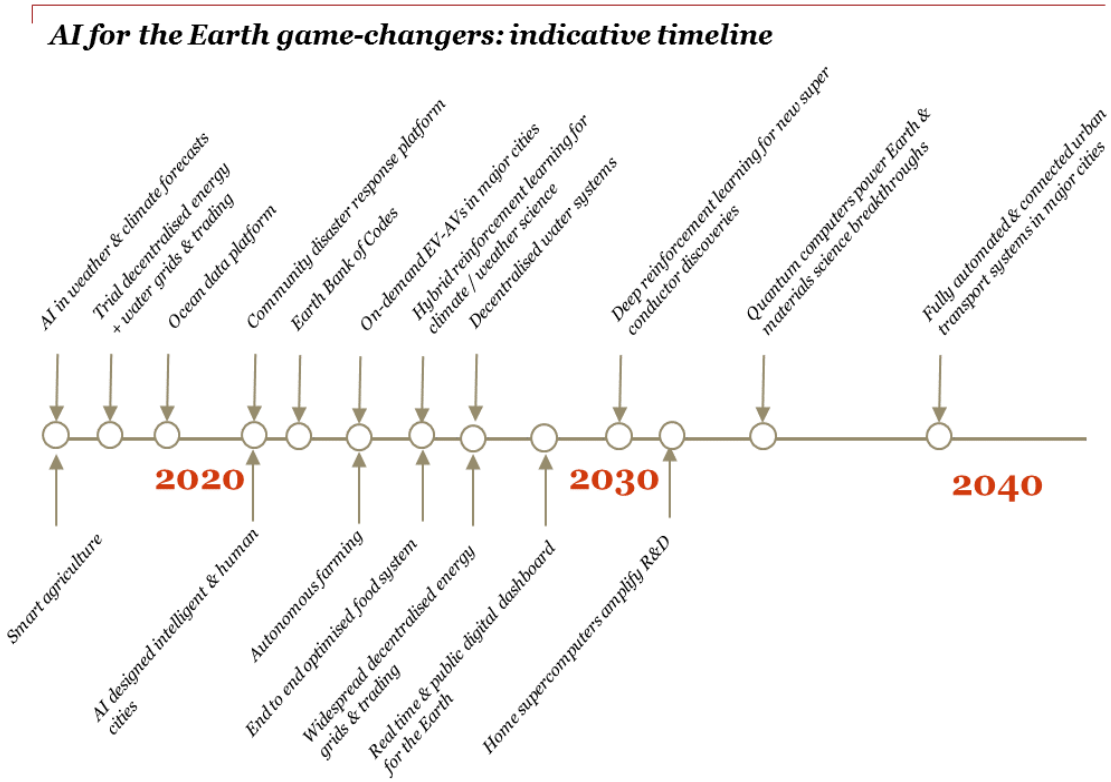

Figure 1: AI for the Earth game changers from World Economic Forum agenda 2018 (https://www.weforum.org/agenda/2018/01/8-ways-ai-can-help-save-the-planet/)

Leading in Health and Wellness: AI supports human health and wellness directly through advances in medical diagnosis, precision medicine, drug discovery, health informatics, robotic surgery, and prosthetics. More indirectly, AI algorithms improve the performance of emergency response systems, health monitoring systems, and serve a variety of assistive and entertainment functions. Figure 2, from Sigmoidal.io, illustrates the burgeoning startup scene covering a wide range of health applications of AI. These companies represent a small fraction of the entire healthcare industry devoted to AI.

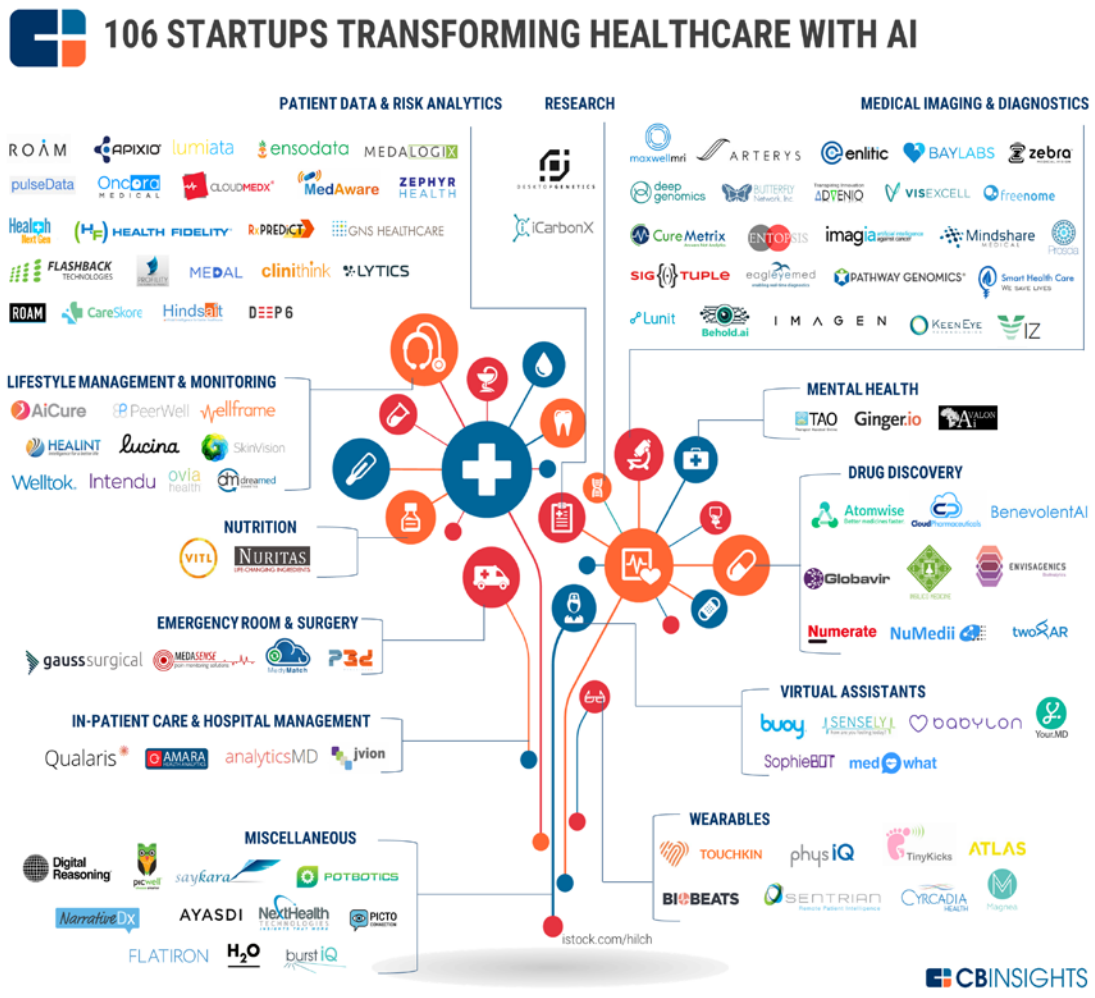

Figure 2: 106 AI startups transforming health care – courtesy Sigmoidal.io. (https://sigmoidal.io/artificial-intelligence-and-machine-learning-for-healthcare/)

Economic Prosperity and Social Progress: AI is arguably the most promising technology to spur economic prosperity in the next few decades, both by opening new markets such as advanced diagnostics, material discovery, computer-assisted tutoring, automated trading, and machine translation, as well as supporting established markets such as manufacturing, logistics, transportation, business and agriculture. In the Emerging Technologies report of World Economic Forum released in 2018, AI was mentioned in three of the top 10 technologies (2. advanced diagnostics for personalized medicine, 3. AI for molecular design and 4. AI that can argue and instruct).

The program contributes to institutional and statewide goals by supporting graduate level education and research in AI both at the master's and doctorate levels. One of the unique aspects of the program is that all students are required to gain experience in working on challenging real-world problems through their final project, thesis or the graduate capstone. We will actively seek industrial collaborators to define and fund the capstone projects, provide

opportunities for internships and mentor students. The AI faculty are part of the CoRIS Institute (https://robotics.oregonstate.edu/), and the NSF-funded Pervasive Personalized Intelligence (PPI) Institute (https://www.ppicenter.org/), both of which will play a large role in finding industrial partners for the student projects and nurturing industry-university collaborations.

The graduate program in AI is attractive for students in Computer Science and Electrical Engineering who would like to address many real-world challenges faced by the society and the industry. It also offers new opportunities for graduate education in the state by opening the doors for students who do not have degrees in Computer Science or Electrical Engineering. Given the importance of AI as an economic engine for the country and the world, the development of the AI program plays a pivotal role for the economic and social progress of Oregon and the United States. Indeed, there is currently a significant demand for AI expertise in many fields such as agriculture, ecology, fisheries. education, health, forestry, and engineering. This allows students who have degrees in these areas to gain additional graduate education in AI and meet the growing demand. Some of the latest research in AI is trying to understand the causal mechanisms underneath societal ills such as crime, poverty and inequality through innovative computational modeling and improved algorithmic technics. We expect these developments to have a large impact on Oregon and elsewhere.

The rise of AI has also posed a variety of ethical and social questions ranging from issues of privacy, algorithmic bias, social relationships, and economic inequality. There is an increasing need for AI researchers to be well-aware of the social science literature to guide public policy. The new degree program offers courses and training in areas that emphasize the social, ethical and policy dimensions of AI, which address the civic and cultural demands of citizenship.

Need for the Program

a. Evidence of market demand

With recent advances in AI from conversational agents to self-driving cars, AI is now a trillion-dollar industry and is expected to quadruple in the next three years. McKinsey report on the economic impact of AI predicts that 70% of the companies will be adopting at least one type of AI technology by 2030, resulting in an additional global economic activity of 13 trillion dollars: https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy

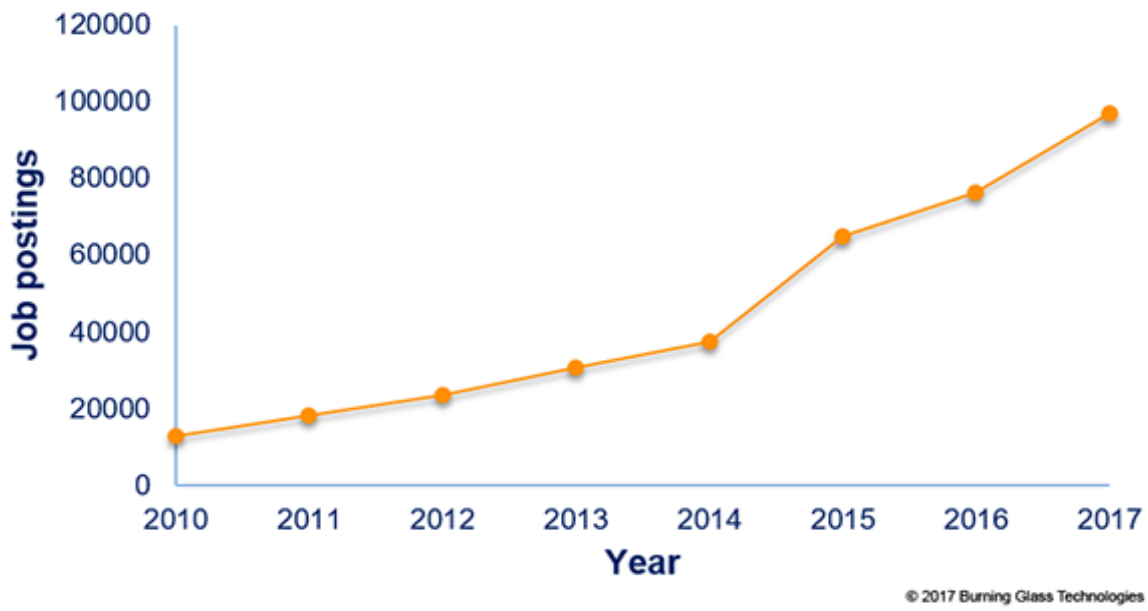

Figure 3: The number of job postings in AI according to Burning Glass Technologies

Figure 3 shows the number of job postings in AI according to Burning Glass Technologies report of 2017 (https://www.burning-glass.com/blog/artificial-intelligence-hiring-expands-beyond-tech-sector/). They predict a growth of 109.4% in Machine Learning jobs and 135.1% in AI jobs during the 2018-2023 period. Given the huge potential growth, the demand for AI skills both at OSU and other universities is skyrocketing. A recently published 20 year community roadmap for AI research also notes, "The need for AI expertise surpasses current production of university graduates with AI skills at the undergraduate, masters, and PhD levels" (https://cra.org/ccc/wp-content/uploads/sites/2/2019/03/AI_Roadmap_Exec_Summary-FINAL-.pdf .

Carnegie Mellon University introduced a BS in AI in the Fall of 2018. They have had a Department of Machine Learning since 1998, which offers MS and PhD degrees in Machine Learning. Northwestern University offers a 5-quarter long Master of Science program in AI https://www.mccormick.northwestern.edu/artificial-intelligence/ . We have not found a stand-alone PhD degree program in AI in the US although several universities appear to be in the process of starting one. There is no similar Oregon public university program in AI at any level.

b. Current and future enrollments in AI at OSU

At OSU the graduate applications to CS and ECE programs ask for a specialization area. Two of the specializations – Data Science and AI – fall under the AI area. Table 2 shows the total number of applicants to these two specializations in comparison to the rest of the areas in Computer Science (CS) for the last five years. The AI applicants include both CS students and ECE students who chose AI as their first preference. As is evident in the table, the demand for AI has steadily increased by 180% in the last five years while the demand for the rest of Computer Science reduced by more than 50%. In 2019-20 academic year, 569 students opted for AI or Machine Learning compared to 144 students for the rest of Computer Science.

Table 2: Graduate applications in AI vs. all other CS fields at OSU in the last five years.

	2015-16	2016-17	2017-18	2018-19	2019-20
AI	203	318	468	540	569
Other CS	298	290	191	184	144

Over the years, our emphasis has been research-oriented PhD students. Due to the limited number of faculty members in the core areas of AI, our acceptance numbers have been relatively low as shown in the first row of Table 3. The number of PhD students who matriculate has been around 10 per year as shown in the second row of Table 3. In spite of the high demand for master's degrees, both the number of master's students who are accepted into the program (row 3) and those who matriculate have been low and uneven.

Table 3: Number of graduate students accepted into PhD and MS during the last five years and the number of students who matriculated (joined the program).

	2015-16	2016-17	2017-18	2018-19	2019-20
PhD Accept	16	18	26	27	41
PhD Matric.	10	9	9	10	13
MS Accept	6	27	2	17	1
MS Matric.	4	11	2	7	1

With the interdisciplinary AI degree and the additional faculty, we anticipate significantly increasing the enrollments. We recently discussed the AI program with our industrial advisory board. While the advisory board members are quite excited about the program, one of their inputs is that many AI jobs in the industry can be done by well-trained master's students. Besides, most of the small companies cannot afford to employ PhD students. As such, we would like to significantly increase the number of MS and MEng students. We envision matriculating approximately 15 PhD students and 30 master's students every year in about five years. Table 4 provides a more detailed year-by-year expected enrollments (head counts).

Table 4: Expected enrollments (head counts) of AI students for the next 5-10 years.

	1st year	2nd year	3rd year	4th year	5th year	10th year
PhD	10	20	30	40	50	60
Master's	15	35	45	50	55	60
Total	25	55	75	90	105	120

c. Current and expected degrees over the next five years

The current average graduation rates for the AI students over the last four years are 5.5 master's students/year and four PhD students/year (Table 5). Both our PhD and MS degrees require one-on-one advising. Typically, PhD degrees take six years and MS

degrees take two to three years. We believe that we can shorten the graduation time and increase graduation rates with the new degree program (a) making the course requirements more aligned with the research and (b) hiring more faculty to advise the PhD and MS students, and (c) increasing the number of master's students. With the additional hires in AI we expect to start producing approximately 10 PhD degrees and 30 master's degrees per year in steady state.

Table 5: Graduation rates of AI students in the last four years.

	2016	2017	2018	2019
MS	5	7	5	5
PhD	2	7	2	5

The expected number of students we graduate in the next five years is given Table 6, assuming that the first batch of students will be admitted in 2021.

Table 6: Expected graduation numbers of students with AI degrees.

	2022	2023	2024	2025	2026
PhD	0	0	0	0	10
MEng	0	5	10	15	15
MS	0	3	10	12	15

d. Demographics of students to be served

The current demographic mix of students who specialize in AI in EECS is shown in Table 6. There are approximately 75% international and 25% domestic students; 75% PhD, and 25% Master's; 78% men, and 22% women. The number of minorities and non-traditional students among the U.S. students is not significant. 64% of students are supported by either a teaching or research assistantship. The new AI program will strive to increase the proportion of domestic students, women, and under-represented minorities as well as non-traditional students. We believe that recruiting students from non-CS and non-engineering disciplines will help improve the diversity of the student body.

Table 7: The demographics of current students who specialize in AI in EECS.

GRAs	23	PhDs	50	Men	52	Citizens/residents	17
GTAs	20	MS	17	Women	15	Foreign	50
Unfunded	24						
total	67		67		67		67

Program Financials

The College of Engineering (COE) has identified AI as one of its strategic priority areas, which is reflected in its hiring plans for the next five to six years. COE has over 220 tenured/tenure-track faculty and it has committed to hiring five additional tenure track faculty and an instructor for the AI program. The additional faculty represents approximately 2% of our college total faculty count. This is broadly consistent with the large funding investments in AI at the national level and the importance of AI to multiple sectors of the new economy. Naturally, we expect enrollments and research to increase, as these are part of the reason AI has been identified as a strategic area.

Expenses: The budget detailed in Table 8 includes salaries for five new tenure track faculty, an instructor, and five additional graduate assistants who can assist in teaching courses or supporting the research of the new faculty. The proposed budget has funding for a program director at 0.1 FTE and an office specialist at 0.5 FTE to support the program coordination including graduate admissions and assessment. Other expenses include a new journal for the library, services and supplies, one-time costs for marketing materials, and furniture, computing and relocation costs for the new faculty hires.

Resources: Funding for the program is expected to come from the highly successful online Computer Science postbac program, retirements (creating open positions) or increased research (which only pays for start-up) in any of the college's academic units since these are college-level decisions.

Table 8: Budget for the program over the next four years.

	Total			
	Fiscal Year 1	Fiscal Year 2	Fiscal Year 3	Fiscal Year 4
Personnel				
Faculty, Tenured/Tenure-track	210,006	324,486	445,644	573,795
Faculty, fixed-term	44,000	45,324	46,683	48,087
Sub-total, Faculty	254,006	369,810	492,327	621,882
Graduate Assistants	132,000	138,600	145,530	152,810
Support Staff	33,000	33,990	35,010	36,060
Fellowship/Scholarship	-	-	-	-
OPE	227,402	298,094	360,767	426,484
Personnel Subtotal	646,408	840,494	1,033,634	1,237,236
Other Expenses				
Library, Printed	-	3,324	3,471	3,628
Library, Electronic	-	-	-	-
Services & Supplies	10,000	5,200	5,400	5,750
Capital Equipment	-	-	-	-
Other Resources Subtotal	10,000	8,524	8,871	9,378
Physical Facilities	-	-	-	-
Construction	-	-	-	-
Major Renovation	-	-	-	-
Other Expenses	300,000	500,000	200,000	-
Physical Facilities Subtotal	300,000	500,000	200,000	-
Total Cost of Program	956,408	1,349,018	1,242,505	1,246,614
Resources				
Current Budget, unit	806,408	1,099,018	1,142,505	1,246,614
Tuition (e campus, differential)	-	-	-	-
Institutional Reallocation from other bu	-	-	-	-
Special State Appropriation	-	-	-	-
Federal Funds and other Grants	-	-	-	-
Fees/Sales	-	-	-	-
Foundation Endowment	-	-	-	-
Tuition remission (GA support)	-	-	-	-
Other, describe: RO/RERF	150,000	250,000	100,000	-
Total Resources	**956,408**	**1,349,018**	**1,242,505**	**1,246,614**

RECOMMENDATION

All appropriate university committees and the OSU Faculty Senate have positively reviewed the proposed program. The Provost recommends that the Board approve the establishment of Interdisciplinary Graduate Program in Artificial Intelligence offering MS, MEng, and PhD degrees and graduate minors effective winter 2021, pending the support of the Statewide Provosts Council and the approval of the Higher Education Coordinating Commission.