MORGAN STATE UNIVERSITY
GROWING THE FUTURE • LEADING THE WORLD

June 3, 2024

Secretary of Higher Education, Dr. Sanjay Rai
Maryland Higher Education Commission
6 N. Liberty Street, 10th Floor
Baltimore, MD 21201

Dear Dr. Rai,

On behalf of Morgan State University, please find attached a proposal to establish the *"Doctor of Philosophy (Ph.D.) in Advanced and Equitable Computing.* This new program will focus on two aspects of advanced computing which Morgan will be uniquely suited to offer: Equitable Artificial Intelligence and Quantum Cryptography & Algorithms. The first area will complement the expertise of our recently established Center for Equitable AI and Machine Learning while the second expands the frontier of knowledge in spaces that benefit from cybersecurity and secure algorithms. We are excited to be introducing this new degree which was approved by the Board of Regents on May 13, 2024.

If additional information is required, please contact Dr. Hongtao Yu at hongtao.yu@morgan.edu or (443)885-3350.

Sincerely,

Dr. David Wilson, President, Morgan State University

Cc: Dr. Hongtao Yu, Provost and Senior VP for Academic Affairs, Morgan State University
Dr. Phyllis Keys, Associate Vice President for Academic Affairs, MSU
Dr. Paul Tchounwou, Dean, School of Computer, Mathematical, and Natural Sciences, MSU
Dr. Emily A.A. Dow, Assistant Secretary for Academic Affairs, MHEC

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Cover Sheet for In-State Institutions
New Program or Substantial Modification to Existing Program

Institution Submitting Proposal	Morgan State University

Each action below requires a separate proposal and cover sheet.

- (●) New Academic Program
- ( ) New Area of Concentration
- ( ) New Degree Level Approval
- ( ) New Stand-Alone Certificate
- ( ) Off Campus Program
- ( ) Substantial Change to a Degree Program
- ( ) Substantial Change to an Area of Concentration
- ( ) Substantial Change to a Certificate Program
- ( ) Cooperative Degree Program
- ( ) Offer Program at Regional Higher Education Center

Payment Submitted: (●) Yes ( ) No
Payment Type: (●) R*STARS # JCMSU226 ( ) Check # JCMSU226
Payment Amount: 850
Date Submitted: 6/3/2024

Department Proposing Program	School of Computer, Mathematical, and Natural Sciences	
Degree Level and Degree Type	Ph.D.	
Title of Proposed Program	Doctor of Philosophy in Advanced and Equitable Computing	
Total Number of Credits	60	
Suggested Codes	HEGIS: 701.00	CIP: 110101.0000
Program Modality	( ) On-campus ( ) Distance Education (fully online) (●) Both	
Program Resources	(●) Using Existing Resources ( ) Requiring New Resources	
Projected Implementation Date (must be 60 days from proposal submisison as per COMAR 13B.02.03.03)	(●) Fall ( ) Spring ( ) Summer	Year: 2024
Provide Link to Most Recent Academic Catalog	URL: www.morgan.edu	
Preferred Contact for this Proposal	Name: Phyllis Keys	
	Title: Associate Vice President for Academic Affairs	
	Phone: (443) 885-3500	
	Email: Phyllis.Keys@morgan.edu	
President/Chief Executive	Type Name: David Wilson	
	Signature: [signature]	Date: 06/03/2024
	Date of Approval/Endorsement by Governing Board:	05/13/2024

Revised 1/2021

Morgan State University

School of Computer, Mathematics, and Natural Sciences

Proposed Doctor of Philosophy (Ph.D.) in Advanced and Equitable Computing (on-campus and distance education)

A. Centrality to Institutional Mission Statement and Planning Priorities

1. Provide a description of the program, including each area of concentration (if applicable), and how it relates to the institution's approved mission.

Morgan State University (Morgan) proposes a new and unique academic graduate degree program; Doctor of Philosophy in Advanced and Equitable Computing (hereafter "Ph.D. in Advanced and Equitable Computing" or "Program"). The Program is offered through the Department of Computer Science (CS) in the School of Computer, Mathematical, and Natural Sciences (SCMNS) in collaboration with the university-wide Center for Equitable Artificial Intelligence/Machine Learning (AI/ML) Systems (CEAMLS), the Clarence M. Michell, Jr. School of Engineering, and the Earl G. Graves School of Business and Management at Morgan.

A.1. Program Description

A.1.1 Motivation

The proposed Advanced and Equitable Computing doctoral program covers Equitable Artificial Intelligence (AI) and Quantum Cryptography & Algorithms. Equitable computing addresses challenges, resolutions and innovations in emotional, empathic, reliable, governable, traceable, resilient and responsible computing for all people. Comprehensive equitable computing has recently been adopted as a principle by the Department of Defense (DoD)[1]. Quantum Cryptography addresses cybersecurity challenges today and in the soon to be quantum age and the post quantum age.

The proposed Advanced and Equitable Computing doctoral program seeks to enhance research capacity and apply advanced and equitable computing approaches to solve real work problems. Morgan is designated as Maryland's Preeminent Public Urban Research University and is striving to reach Carnegie Research R-1 status. It is imperative that Morgan establishes this doctoral program to educate and train high level professionals entering into industry, academia, and government to comprehensively improve advanced computing with the much needed, but unfortunately lacking, equitable aspects.

This Ph.D. program, both theoretical and applied, is a natural extension of the already established Master of Science (MS) in Advanced Computing degree program in the CS Department at Morgan,

[1] https://www.defense.gov/News/News-Stories/article/article/2094085/dod-adopts-5-principles-of-artificial-intelligence-ethics/

which enrolled 42 students in spring 2024 and currently has 167 students on record (continuation and new applicants). Not only will the proposed Ph.D. program be attractive to prospective applicants outside of Morgan, but also, equally important, it will offer graduates from our MS in Advanced Computing Program an intuitive important extension, and a cohesive continuation of their graduate education and prepare them to assume roles as university faculty members, senior researchers, and senior-level professionals in the high demand computing field with equitable technological advancements. Demonstrably, the proposed program is a unique Advanced and Equitable Computing doctoral program focusing on new and on demand frontiers on quantum cryptography and equitable (emotional, responsible, resilient, and empathic) AI in the State of Maryland. These highlights include, but are not limited to, the following:

Equitable AI, a new frontier in research and development in AI that incorporates emotional, empathic, and responsible computing letting AI systems to express human feelings, affections, and emotions while making sure the computing models and outputs are inclusive, transparent, and responsible to all without prejudice or bias. A few universities have started research in related areas and produced promising results in depression assessment, support at-risk young adults, stress prediction, emotion detection, affection recognition, and deep fake detection, etc. Morgan CS faculty have been in collaboration with faculty at MIT on emotion computing research. There have been 12 students involved in this research. A number of faculty at Morgan have been conducting research in responsible AI, to employ AI in a safe, trustworthy, and ethical way and increase transparency and reduce bias in AI applications.

On the equitable computing side, Morgan has recently established a Center for Equitable AI and Machine Learning (AI/ML) Systems (CEAMLS) with a $3.1 million State budget each year, $2 million Maryland House of Legislation (one time), A $9 million DoD grant, a number of other grants and corporate donations, and 14 new faculty members. CEAMLS facilitates the research, development of standards, identification of new methods, and advancement of innovative technologies that benefit all people, especially underrepresented minorities. CEAMLS serves as an interdisciplinary nexus for thought leadership and research in the application of fair and unbiased technology and its applications. The Center remains rooted in scholarly stewardship, cultivating the next generation of students at all levels, as well as life-long learners across industries and areas of study. Currently, CEAMLS has 14 ongoing research projects addressing the ethical, responsible, and emotional aspects of equitable AI/ML systems.

Quantum Cryptography and Algorithms, a new frontier to improve trust, cybersecurity, secure algorithms, architectures and systems, and safeguard the data from vulnerabilities and attacks including wiretapping, eavesdropping, or man-in-the-middle attacks guaranteed by the quantum mechanics theory. Morgan CS department has a strong research team with cutting-edge quantum crypto equipment and simulation devices, which is one of few in the nation and only one in the DC metropolitan area. The team has collaborated with IBM and other world top quantum cryptography companies. The NSF has recently awarded Morgan computer science quantum team three quantum crypto-related grants in conducting cutting-edge research to safeguard the current and post-quantum security and to establish a quantum crypto track for undergraduate students and a certificate program for graduate students. At present, Morgan CS has offered five quantum computing/crypto classes; six more classes are being developed. A total of 87 students have taken quantum computing/crypto courses offered by the CS department. The department has received

three National Science Foundation (NSF) grants in quantum cryptography research and workforce development in recent years.

Domain-specific architecture is a frontier in theoretical and applied research in system design, application and verification. The research areas span not only high-performance hardware but also in interconnection networks and application software and algorithms. Transistor density on a semiconductor wafer has slowed down from roughly double every two years, according to Moore's Law. Computer speed cannot only rely on innovation in silicon but has to come from new architecture design and development. Domain-specific computer architecture is to design new computers and systems specifically tailored to operate very efficiently within the confines of a given specific domain, in contrast to nowadays computers that are "general purpose", meant to be utilized in any applications, according to John Hennessy and David Patterson, who are the recipients of the ACM Turing Award, the highest award in Computer Science. Morgan CS faculty have unique expertise in this area with journal and conference publications, a dedicated lab, and two books (one ranked as the best seller at Amazon for more than a month).

Advanced and equitable computing specializations are expected to be the driver of incredible job growth and innovation throughout our economy. Lack of equity and ethics makes it vulnerable in many research fronts especially in equitable AI and ML systems. Cybersecurity has been a top concern for government and private sector and cyber workforce development has been one of the top priorities to fill the much-needed job vacancies. With the advances of quantum computing technologies, today's strong encryption could become insecure within the next decade or so. Development of quantum-enhanced security such as quantum cryptography and post-quantum cryptography become essential. Computation, from modeling and simulation to data mining, drives progress in many research areas, and has helped to create new fields. Cloud computing, cybersecurity, and AI occupations are the number one source of all new wages in the U.S. and make up over half of all projected new jobs in STEM fields, making them the most in-demand college degrees by far. As more and more students seek to graduate with bachelor's and master's degrees in advanced computing, computer science, electrical engineering, and information science to fill this employment gap, holding a doctoral degree in advanced and equitable computing would help the underrepresented groups we serve to stand out from the pack and be considered for the most competitive positions both in academia and industry. The advantages of a deeper knowledge of advanced and equitable computing in many domains has also led to the recent emergence of new degree programs at several institutions. The doctoral program in Advanced and Equitable Computing program at Morgan would provide a specialized focus in an area of science and technology, helping develop skills and career prospects for underserved students. Adding an online option increases the possibility for more students, especially IT professionals currently in the workforce, to study in the program with the flexibility of their own time and schedule.

A.1.2 Program of Study

The required minimum coursework for the Ph.D. in Advanced and Equitable Computing is to complete sixty (60) equivalent credit-hours beyond the bachelor's degree or thirty-six (36) equivalent credit-hours beyond the master's degree, pass comprehensive examinations, and submit an acceptably written dissertation. For candidates who hold equivalent industry certificates, the maximum credit hours that can be applied to this program is eighteen (18), after being evaluated

by the graduate committee.

The graduate courses (Tables A and B) are comprised of: (a) Core Courses that are mandatory for all graduate students; (b) Elective Courses (each credit is equivalent to 1 credit-hour of graduate coursework); and (c) Dissertation Research/Defense. For professionals with equivalent industry certificates, the maximum credit hours that can be applied to this program is 18, after being evaluated by the graduate committee.

Course Type	Equivalent Credit-Hours
Core Courses	18
Elective Courses	18
Dissertation Research and Dissertation Defense	24
Total	**60 credit-hours**

Table A: Credit breakdown for students pursuing the Ph.D. degree following the bachelor's degree (60 equivalent graduate credit-hours required beyond the Bachelor's Degree).

Course Type	Equivalent Credit-Hours
Core and Elective Courses	12
Dissertation Research and Defense	24
Total	**36 credit-hours**

Table B: Credit breakdown for students pursuing the Ph.D. degree following the master's degree (36 equivalent graduate credit hours required beyond a Master's Degree).

Students who only have a bachelor's degree or do not have a master's degree in the approved degree program listed in Table C will be required to take a minimum of 18 credit-hours of core courses, a minimum of 18 credit-hours of elective courses, and 24 credit-hours of dissertation research/defense.

Students with a MS degree in the approved areas listed in Table C will be required to take a minimum of 24 equivalent graduate credit-hours of dissertation research/defense area courses, and a minimum of 12 credits-hours in core and elective courses. Additionally, pending program review and approval on a case-by-case basis, there may be other master's degrees that can satisfy the prerequisite requirements of Table C.

MS in Advanced Computing/Computer Science
MS in Electrical Computer Engineering
MS in Software Engineering, AI, Cybersecurity, Data Science
MS in Information Science/Technology .

Table C: List of approved Master's Degree programs for direct admission into the Ph.D. in Advanced and Equitable Computing program.

All candidates need to develop a dissertation proposal, conduct original research, successfully defend a dissertation, and maintain good academic standing to receive the doctoral degree.

A.1.3 Market Drivers

There is a severe shortage of underrepresented professionals in academia, government, and industry to fill jobs in advanced computing and technology, especially exacerbated with equity in consideration. This new program provides a platform for a growing population of students including those who are underrepresented minorities (URM) to advance their skills necessary for attaining better opportunities in complex and rapidly evolving technological environments, higher education, and high-tech companies. Graduates will be uniquely prepared for specialized jobs with focus on an area of equitable and emerging technology, involving cutting-edge aspects of equitable AI and quantum cryptography that are fundamentally important, practically relevant, and equitably widespread. The possibility of completing a doctoral degree in Advanced and Equitable Computing remotely makes it possible for working professionals who would otherwise not be able to study in classrooms during working hours to enroll in this program.

The enrollment in BS in Computer Science at Morgan has **tripled** in the last five years and students have constantly shown interests to pursue advanced degrees.

The MS in Advanced Computing program at Morgan is also successful and has been rapidly expanding. The enrollment increased from 12 to 60 within three years. Unfortunately, at most universities, their CS departments have been having difficulties hiring faculty who are URMs. It was a challenge for Morgan CS department as well. The department currently has four openings with over a hundred applicants. Unfortunately, very few are URMs. The new program will educate and train computer scientists, especially URM professionals, to fill in the gap in academia and industry.

The CS department is dedicated to fulfilling the mission by preparing students, especially URM students to be the next generation of scientists and professionals who will be able to effectively compete in the challenging global society and address the equity and social justice of computing, technology and the society.

A.2. Strategic Goals Support and Affirmation

2. Explain how the proposed program supports the institution's strategic goals and provide evidence that affirms it is an institutional priority.

Transformation Morgan 2030 Strategic Plan for Morgan State University (2021 - 2030) (the Strategic Plan) consists of six broad goals including Enhancing Student Success, Enhancing Morgan's Status as a Doctoral Research University, Improving and Sustaining Morgan's Infrastructure and Operational Processes, Growing Morgan's Resources, and Engaging with the Community. These Strategic Plan goals guide the development and implementation of the University's academic programs, student services, and institutional budgets. The Ph.D. in Advanced and Equitable Computing program supports at least three of Morgan's Strategic Plan goals:

> **Goal 1**: **Enhancing Student Success.** The Program supports Morgan's goal in leading the state of Maryland in graduating underrepresented minority students in STEM disciplines

by offering challenging, internationally relevant academic curricula. The establishment of the unique Ph.D. in Advanced and Equitable Computing with equitable technology challenges enhances Morgan's instructional capacity to train professionals to serve the City of Baltimore, the State of Maryland, the region and nation by attracting underrepresented students to this unique program. This program will also contribute to the Strategic Initiatives for Morgan to reach R-1 designation and initiatives of the Center for Equitable AI/ML Systems and Cybersecurity Assurance and Policy (CAP) Center to expand academic program offerings, including new and online degree programs and up-to-date curricula, as well as, enhance research and scholarly activities and capabilities.

Goal 2: **Enhancing Morgan's Status as a Doctoral Research University** As a recently designated Carnegie high research activity university, the Ph.D. in Advanced and Equitable Computing will have a profound impact on maintaining and growing our research stature by increasing Ph.D. production, number of publications, and sponsored research funding.

Goal 3: **Growing Morgan's Resources** The Program expands Morgan's human capital and financial resources by investing in the professional development of faculty, staff, and students, establishing collaborative relationships with private and public entities.

In mid-September 2021, Morgan convened a Blue-Ribbon Panel on Research Program Expansion. The Panel was charged with assisting us in "identifying a few potential peaks of excellence within a number of key technology areas where Morgan could and should develop programs of national prominence. "Trustworthy Artificial Intelligence" was the first of five priority areas identified.

Morgan CS department has established a Trustworthy AI Lab with a number of equitable AI/ML related projects and publications. Bezos Fund, Meta (Facebook) and Google have awarded projects on equitable AI/ML to Morgan CS and are collaborating with Morgan on a number of research fronts. A world class quantum cryptography lab with industry level Quantum Key Distribution devices has been established. To date, this is one of the few quantum-enhanced network labs in academia in the country and around the world. In collaboration with the National Labs and National Security Agency (NSA), Morgan computer science students and faculty are able to use curricula co-developed by NSA and access NSA High Performance Computing labs.

B. Critical and Compelling Regional or Statewide Need as Identified in the State Plan

1. ***Demonstrate demand and need for the program in terms of meeting present and future needs of the region and the State in general based on one or more of the following:***
   a) ***The need for the advancement and evolution of knowledge***
   b) ***Societal needs, including expanding educational opportunities and choices for minority and educationally disadvantaged students at institutions of higher education***
   c) ***The need to strengthen and expand the capacity of historically black institutions to provide high-quality and unique educational programs***

2. ***Provide evidence that the perceived need is consistent with the Maryland State Plan for Postsecondary Education***

The proposed program is consistent with the State of Maryland's goals for maintaining and strengthening a preeminent statewide array of postsecondary institutions. It responds to the crucial need as highlighted in the 2021-2025 Maryland State Plan for Postsecondary Education: Student Success with Less Debt by ensuring "equitable access to affordable and quality postsecondary education for all Maryland residents" and promoting and implementing "practices and policies that will ensure student success" and fostering "innovation in all aspects of the Maryland higher education to improve access and student success". The State of Maryland enjoys a national and international reputation as it "is among the nation's leaders of innovation in higher education, highly ranked in research and development with 72 federal laboratories," which is also one of the core values of MSU.

B. 1. Demonstrate Demand and Need for the Program in Terms of Meeting Present and Future Needs of the Region and the State

While Silicon Valley benefits from its tech giants, such as Google, Facebook, Apple, and the like, the Washington-Baltimore region and the state of Maryland as a whole benefit from being close to the US Capital, Washington, D.C. and to the sprawling region of Northern Virginia. MSU is very close to federal agencies: NASA, NSA, NSF, NIH; Military establishments: RDECOM, CECOM, Naval Air Systems Command, ARL, APL; contractors: Lockheed Martin, Northrop Grumman, and other tech industries. The region has a diversified population with all kinds of job opportunities in a wide range of fields from defense to cyber security to IT to health care to Biotechnology. Maryland is also home to more than 60 federal agencies and twice as many federal laboratories (74) as any other state. The state features a diversified economy with the second highest concentration of professional and technical workers among the states. Combing through its database, Indeed.com (a Google-like job listing aggregator) put together a list of the top ten metropolitan areas with the most job listings for computer scientists, the Washington, D.C. region with its many defense contractors and government jobs, comes in at number one.

The vibrant economy in this region includes industries and labs conducting application development and research in equitable AI/ML and quantum cryptography and algorithms, which is dependent upon an educated and professional IT workforce. According to The Computing Technology Industry Association 2021 report, Maryland is fifth in the country for total tech workers in the workforce at 9.5%. Maryland is also third in the nation for the percentage of research and development professionals. Baltimore is the third best city for women in technology based on jobs, which observed a 36% growth in the number of tech sector jobs overall from 2018 to 2021, according to data from the U.S. Census Bureau.

MSU is a major economic engine for the city and state annually producing $1 billion in statewide economic impact, supporting 6,500 jobs and generating $47 million in state tax revenues. Its proximity to Baltimore, Washington DC, Annapolis and Northern Virginia regions coupled with demand for CS professionals has made the needs of degree programs like this more apparent and will open many opportunities for graduates in federal and state agencies, prominent defense and tech industries, and the commercial sector.

B.2. Provide Evidence that the Perceived Need is Consistent with the Maryland State Plan for Postsecondary Education

The need for a PhD in Advanced and Equitable Computing program is consistent and well aligned with the three goals: Access, Success and Innovation of Maryland's 2021-2025 State Plan for Postsecondary Education. The proposed program is conformed to the first goal **"Access"** which "ensure equitable access to affordable and quality postsecondary education for all Maryland residents." Closing the accessibility and achievement gap is an ongoing endeavor for Maryland, which is a leading state in postsecondary education by maintaining the ongoing commitment to addressing equal access, success, and opportunity through a variety of focused programs. The need for a Ph.D. program in Advanced and Equitable Computing to serve both under-represented minority student population, white, or Hispanic students with affordable and lower educational cost compared to other private and public universities in this region is a step closer to fulfill the goal of the state which has a fundamental commitment to equity, equality, and diversity. The state plan also strives for ensuring student "**Success"** by promoting and implementing practices and policies, such as supporting "the unique missions of Historically Black Colleges and Universities" and enhancing "diversity by fostering collaborations between Historically Black Colleges and Universities and traditionally white institutions". Hence, this proposal from an HBCU for a graduate program will definitely promote the above goal and be very consistent with the state plan and commitment to equal education opportunities. This program will also allow "long-term graduate education opportunities when considering a student's career trajectory" and will make it easier to "expand support for research and research partnerships" which are depicted as strategies for fostering innovation in all aspects of Maryland higher education to improve access and student success. **"Innovation"** is also one of the six core values of MSU that encourages and supports in all forms of scholarship including the discovery and application of knowledge in teaching and learning and in developing innovative products and processes of "business-driven credentials."

C. Quantifiable and Reliable Evidence and Documentation of Market Supply and Demand in the Region and State

1. ***Describe potential industry or industries, employment opportunities, and expected level of entry (ex. Mid-level management) for graduates of the proposed program***
2. ***Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program***
3. ***Discuss and provide evidence of market surveys that clearly provide quantifiable and reliable data on the education and training needs and the anticipated number of vacancies expected over the next 5 years***
4. ***Provide data showing the current and projected supply of prospective graduates.***

The demand for employees with advanced computing expertise is high and it has grown steadily over time. According to data from the Bureau of Labor Statistics (BLS) employment in computing occupations grew by nearly a factor of 20 between 1975 and 2020, nearly twice as fast as production of information system bachelor's degrees. BLS has projected that demand for Advanced Computing workers will continue to grow over the next decade at a rate higher than that of overall job growth, particularly as computing becomes more central to a wider range of industrial sectors. Computer science-related jobs such as equitable AI and quantum computing are expected to grow 11% between 2014 and 2024, according to the BLS—substantially higher than

the seven percent growth expected for all occupations. According to Burning Glass Labor Insights, the employment demand is particularly intense, and the growth is expected to be even higher for certain occupations: 14% for computing and information research scientists, 20% for software developers including quantum software developers, and 23% for computer systems analysts. This healthy growth will keep the job market stable for Computer Science degree holders, ensuring continued value from their degree.

At the current number of graduates, 50,962 bachelor's degrees, 22,777 MS degrees, and 1,826 Ph.D. 's in computer science, the supply of computer-science knowledge coming out of America's universities is insufficient to meet growing demand. Currently, it is estimated that there are more than 500,000 open computing jobs across the country, and there are over 115,000 total computer science-related jobs in Maryland with almost 20,000 openings (4.8 times the average demand rate in Maryland). Data from the Conference Board for job demand, the Bureau of Labor Statistics for state salary, and national job projections data indicate that the average salary for a computing occupation in Maryland is $103,646, which is significantly higher than the average salary in the state ($57,270). A recent study by the Southern Regional Education Board projects that 69% of jobs created in Maryland by 2025 will require at least a four-year degree. Maryland's growing reputation as a center of innovation makes it the home of more and more high-tech businesses that demand a highly educated workforce. The challenge for Maryland universities is to widen the pipeline of those workers entering the labor force.

Demand for AI and Quantum Computing workers is expected to grow by 10 percent over the next decade in Maryland. As a proof, a recent search by Indeed.com reveals that there are 174 new jobs in Baltimore with a requirement of Ph.D. in advanced computing degree, and there are close to 10,000 openings throughout the nation. Yet, state colleges and universities graduated fewer than 3,000 computing majors yearly on average, and only 20% were female and the number of graduates with an Ph.D. degree in Advanced and Equitable Computing is even much lower. Hence, at the current rate, the supply of computer science workers in Maryland still falls short of the demand demonstrated by the current market, let alone demand expected in the future.

For individuals already working in the information technology (IT) sector, a doctoral degree can provide a career boost by enabling professionals to expand their expertise in the field. For example, a doctoral degree gives students specialized skills in one or more areas of technology, including software development, data science or artificial intelligence, and machine learning. A Ph.D. degree in Advanced and Equitable Computing can also increase salary potential. According to a 2020 PayScale.com report, a Ph.D. degree in Advanced Computing and engineering was the 15th highest-paid of all graduate degrees. Early career pay was reported to be $95,900, and mid-career pay jumped to $134,000 per year. For example, most jobs for computer and information research scientists require a doctoral degree in Advanced Computing or a related field which are expected to grow 19% (much faster than average) between 2016 and 2026 with a median pay of $124,520 per year (2021) according to the U.S. Bureau of Labor Statistics.

Equitable AI and Quantum Computing and Security rank among the top emerging jobs. According to LinkedIn's 2021 U.S. Emerging Jobs Report there are 9.8 times more Machine Learning Engineers working today than five years ago with 1,829 open positions listed on the site today. The career path in equitable AI and quantum cryptography and algorithms begins with a solid software

engineering background. There are 29,187 Software Engineering jobs available today, making this job the most popular regarding Glassdoor postings according to the study.

According to Forbes, Demand for quantum computing expertise continues to increase exponentially and will accelerate in 2023 and beyond. Forbes also indicates that there will be tens of thousands of quantum-computing positions available in the U.S that need a terminal degree. According to the Association for Computing Machinery (ACM), quantum computing and AI are among the top 10 jobs for the next decade.

MSU should capitalize on the growing interest and professional opportunities in advanced and equitable computing and expand its offerings to accommodate the growing demand of computing skills in those above fields. We expect the degree program to be successful in this regard.

D. Reasonableness of Program Duplication

1. Identify similar programs in the State and/or same geographical area. Discuss similarities and differences between the proposed program and others in the same degree to be awarded.

Although the Ph.D. in Computer Science is offered in several institutions in Maryland, the proposed Advanced and Equitable Computing Ph.D. program is unique. Our study shows that, Ph.D. in CS, broadly defined, is offered at Bowie State University, John Hopkins University, Loyola University, University of Maryland Baltimore County, Capitol Technology University, and University of Maryland College Park within the State of Maryland. Towson University offers a Ph.D. in Information Science.

While Capitol Technology University expands beyond general CS to include Ph.D. programs in machine learning and in quantum computing, their course listings for these degrees do not show any curriculum having the focus on equitable artificial intelligence or cryptography. Their programs are both fully online and require 60 credits for completion.

Johns Hopkins University (JHU) offers a Ph.D. in Computer Science with a range of tracks including data science, cloud computing, cybersecurity, and software engineering. JHU currently is the only institution in MD to offer an online Ph.D. CS degree. The JHU program requires at least three and a half years to complete.

University of Maryland Baltimore County offers a general Ph.D. in computer science with no focus areas; Bowie State University offers a Ph.D. in computer science with a specialty in information technology; Loyola University Maryland offers PhD in computer science with web programming and networking tracks; and University of Maryland College Park offers a general PhD in computer science with no tracks, but with a wide range of research areas. However, none has significant overlap with our program given our focus on advanced and equitable computing. The course-by-course comparisons between the proposed program and programs offered at other universities are listed in Appendix A.

The Morgan Ph.D. in Advanced and Equitable Computing program will be a **unique** program in the State of Maryland that has the option for students to study remotely, in addition to studying onsite (students may choose modality course-to-course). This will attract both working professionals and college graduates. A residence component may be required if students do not have the adequate lab equipment to conduct the research or the lab equipment cannot be accessed remotely. In addition to the flexible modality, the proposed program prepares students with the foundation in emerging areas of equitable AI and quantum cryptography so they can lead a team to conduct research and implement cutting-edge projects. Study shows that onsite/remote learning modality can attract more domestic students especially underrepresented students to continue their study beyond the bachelor's degrees.

Morgan is collaborating with Google in AI/ML with grants and learning materials. Morgan also collaborates with Amazon to improve research and teaching in the CS department. Morgan students can use Amazon Web Services (AWS) (free) in hands-on learning about machine learning, cybersecurity, IoT, and data analytics. IBM has awarded 6 Master's awards to the Morgan computer science department in quantum computing. The agreement with NSA, Carnegie Mellon University (CMU), and National Labs allows Morgan students and faculty to use their HPC for free in learning and research. The proposed degree program has a strong focus on workforce development. Most classes have labs and projects that use real-world problems developed collaboratively with industry professionals, a distinction of the proposed program from other existing programs.

In summary, the proposed Advanced and Equitable Computing doctoral program focuses on Equitable AI and Quantum Cryptography & Algorithms. It addresses challenges, resolutions and innovations in emotional, empathic, reliable, governable, traceable, resilient and responsible computing and does not duplicate any programs in the State. Instead, it complements the existing programs with a strong workforce development focus and advanced and equitable computing foundation.

2. Provide justification for the proposed program.

This high-demand also presents an opportunity for MSU to provide underrepresented minority students to major in PhD in Advanced and Equitable Computing.

The interdisciplinary, transdisciplinary, theoretical and practical nature of this PhD program in Advanced and Equitable Computing provides a unique platform for underrepresented students at an HBCU to enhance their versatility and marketability in the high-tech job market.

E. Relevance to High-Demand Programs at Historically Black Institutions (HBIs)

1. Discuss the program's potential impact on the implementation or maintenance of high-demand programs at HBI's

With the growing enrollment of computer science undergraduate majors at MSU from 204 to 586 in the last five years, there is a high demand to provide a platform for those that aim at pursuing

higher degrees to be able to compete for high-paid and important positions in high-tech companies and higher education institutions. Despite a growing number of institutions offering such programs, the offering of such programs mainly for underrepresented minorities is rare. This is due to several issues such as high expenses of studying in private institutions, shortage in capacity of taking a larger body of students, and affordability for underrepresented minority communities. As such, MSU can play an important role in addressing these issues. The three HBCUs in Maryland, Bowie State University, Coppin State University, and University of Maryland Eastern Shore offer graduate programs in Advanced Computing. However, none have significant overlap with our program. In fact, the concept of equitable AI and quantum cryptography is absent in their programs. Similarly, the certificates and titles presented in those programs with respect to the courses and credits are different from ours.

In addition, the offering of the Ph.D. in Advanced & Equitable Computing provides a platform for fulfilling the pipeline of underrepresented computer scientists to seek employment in academia, industry, and government. The introduction of such programs encourages students to continue their education to attain skills and experience to obtain better positions available at high-tech companies, in higher education, and in research organizations.

The Department of Computer Science at MSU has recently initiated collaborations with Google and Facebook to train high-skill students in computer science to promote diversity in large high-tech companies. These companies have agreed to provide the department with trainers, facilities, and equipment to develop its infrastructure to attain this objective. Also, the department of computer science in collaboration with Google started a program in Silicon Valley to train students from underrepresented communities and prepare them with skills and expertise to be recruited in this company. In addition, these companies offer internships to over 20 MSU computer science students per year to enhance motivation of our underrepresented minority students to obtain necessary skills to join these companies.

Considering these collaborations, offering a doctoral degree with a focus on equitable AI and quantum cryptography and algorithms can further promote such activities.

F. Relevance to the Identity of Historically Black Institutions (HBIs)

1. Discuss the program's potential impact on the uniqueness and institutional identities and missions of HBIs.

MSU is a historically black university with the unique designation as Maryland's "Preeminent Public Urban Research University." MSU serves an ethnically diverse student body consisting of full-time and part-time college-age students and adult learners. MSU is committed to the academic success and achievement of all its students[2].

With the growing number of enrollments at our undergraduate and master's level in computer science and the small capacity of the PhD program in Advanced and Equitable Computing in the

[2] www.morgan.edu/Documents/ACADEMICS/Academic.../ucat_AcademicAffairs.pdf

other HBCUs in Maryland, our proposed program can play an important role in developing such infrastructure in HBIs within the State of Maryland.

G. Adequacy of Curriculum Design and Delivery to Related Learning Outcomes (as outlined in COMAR 13B.02.03.10)

1. Describe how the proposed program was established, and also describe the faculty who will oversee the program.

PhD in Advanced and Equitable Computing students are expected to proactively pave a foundation of knowledge and skills in equitable AI and quantum security out of coursework, independent study, projects, and research. Along with completion of the graduate degree, students will identify and address problems in heterogeneous domains, use the foundation and skills to the professional domain, and contribute and disseminate the progress with the community and to the science.

2. Describe educational objectives and learning outcomes appropriate to the rigor, breadth, and modality of the program.

Learning Outcomes

Students pursuing the Ph.D. in Advanced and Equitable Computing, upon completion of requirements, will be able to:

1. Understand and explore in-depth knowledge in equitable AI and quantum cryptography and algorithms from the perspective of different disciplines and application domains.
2. Demonstrate high-level understanding of principles, contributors, developments and contemporary applications of equitable computing and quantum security.
3. Solve practical and challenging ethical, equitable, and quantum security problems.
4. Use and deploy computing principles and tools with equity.
5. Collect data through extensive reading, viewing, listening and researching in both print and electronic media online and in databases and evaluate sources for credibility and appropriateness for transparency and fairness.
6. Demonstrate knowledge of problem-solving techniques in the basic concepts and principles of both theoretical and applied sciences.
7. Enhance skills and demonstrate the impact through both project and dissertation; For professionals, to gain necessary foundations and skills through appropriate course work.
8. Use the knowledge and skills acquired for advancement in the workplace in different application domains.

3. Explain how the institution will:

a) provide for assessment of student achievement of learning outcomes in the program.

- Students will undergo formative and summative assessment throughout the coursework (Obj. 1-5)

- Students will need to take and pass comprehensive examination(s) as a partial requirement for candidacy (Obj. 1-6)
- Students will be required to perform research in support of a dissertation research project leading to the dissemination of scholarly work through scientific presentations (poster and oral); research publications (Obj. 6-8)

b) document student achievement of learning outcomes in the program.

- Students' academic performance in courses (required and electives) will be monitored closely. (Obj. 1-4)
- Research progress reports will be generated by students and reviewed by the research mentors and program directors to ensure timely completion of degree milestones. (Obj. 5-6)
- A database will be constructed to track student awards & fellowships (applications and awarded), presentations and publications (Obj. 6-8).

4. Provide a list of courses with the title, semester credit hours, and course descriptions, along with a description of program requirements.

A list of courses with title, semester credit hours and course descriptions, along with a description of program requirements

Program Curriculum/Course Requirements

The required minimum coursework for the Ph.D. in Advanced and Equitable Computing is 60 graduate credits beyond the Bachelor's degree and 36 graduate credits beyond the Master's degree. Six courses (18 credits) can be applied for closely related industry certificates, after being evaluated by the graduate committee.

A. Pursuing a Ph.D. from the Bachelor's Degree (60 Credits)

Doctoral Dissertation: **12 Graduate Courses** including **6** core courses (**18 credits**) Students need to take at least **one course** from each of the four knowledge areas for a total of 6 courses during the first year. Students need to take another **6 courses** (**18 credits**) in their second year from Electives and may take a few from the core courses or courses from other departments (based on the adviser recommendation). An adviser will be assigned to students in the second year after the qualifying exam.

The remaining **24 credits** will be for dissertation research where courses will be selected from one or more combinations of Independent Study, dissertation research (4 courses), Special Topics in Computer Science, Research Seminar, and Dissertation Guidance/Dissertation Defense.

1. Estimated Time to Complete the Degree:
   Four years or 48-months for full-time students. The estimated time can be longer for those who study part-time or want to take a traditional approach with a slower pace.

2. Prerequisites/Admission Requirements
   a. Minimum GPA and application requirements of the School of Graduate Studies determined by the program director.
   b. BS degree in Computer Science or related areas (assessment/approval needed by the program director or department chair).

3. Course Requirements:

   a. **Core Courses** (18 credits)
   One must complete, with a grade of "B" or higher, six (6) courses from the following knowledge areas:

   Equitable AI

   - COSC 502: Equitable Artificial Intelligence (3 credits)
   - COSC 672: Emotional Reinforcement Learning (3 credits)
   - COSC 680: Bias Detection in Image Understanding (3 credits)
   - COSC 726: Explainability and Fairness in Machine Learning (3 credits)

   Quantum Cryptography and Algorithms

   - COSC 586: Quantum Computing (3 credits)
   - COSC 614: Cryptography and Cryptology (3 credits)
   - COSC 686: Quantum Algorithms and Architecture (3 credits)
   - COSC 724: Post Quantum Cryptography (3 credits)

   Prerequisite courses: data structure, discrete math, computer organization, computer architecture, introduction to cybersecurity, software engineering, computer networks. Applicants whose prior education does not include the prerequisites may be admitted under provisional status, followed by full admission once they have completed the missing prerequisites. Exceptions can be made by the program director or the department chair.

b. Elective Courses (18 credits)
   Students must complete at least 6 other courses from the following elective courses or from the core courses that were not taken before, or courses from other departments (based on the adviser recommendation).

COSC 511: Design and Analysis of Equitable Algorithms	3
COSC 512: Software Engineering and Formal Methods	3
COSC 558: Advanced Network Security	3
COSC 612: Deep Learning in the Cloud	3
COSC 711: Quantum Algorithms and Applications	3
COSC 721: Equitable High-Performance Computing	3
COSC 722: Equitable Machine Learning Applications	3
EEGR 750: Trustworthy Machine Learning	3
EEGR 755: Advanced Software Assurance	3
INSS 854: Information Systems Security	3

Note: Any core not previously taken can be taken as an elective course.

c. Dissertation Research Courses (24 credits)

The remaining **24 credits** will be for dissertation research where courses will be selected from the following:

COSC 790: Independent Study	3
COSC 791: Special Topics in CS	3
COSC 792: Research Seminar	3
COSC 801: Dissertation Research I	3
COSC 802: Dissertation Research II	3
COSC 803: Dissertation Research III	3
COSC 804: Dissertation Research IV	3
COSC 997/998: Dissertation Guidance/Dissertation Defense	3/9* credits, repeatable

* Note: The student will continuously register in Fall and Spring terms for COSC 997 (Dissertation Guidance) until the doctoral dissertation is completed and submitted to the School of Graduate Studies for review. The course is used only when the curriculum has been completed, and the student is completing the research and writing of the dissertation. The course registration maintains the student status as a matriculated, full-time student (student registers for 3 credit hours each semester but is acknowledged as having a 9 credit hours load). After the Intent to Defend the doctoral dissertation form has been accepted by the School of Graduate Studies, this course registration will be changed to COSC 998 (Dissertation Defense) for the given semester and count for 3 credit hours of curricular coursework. Other courses cannot be substituted for COSC 997. The only eligible grade for COSC 997 (Dissertation Guidance) is the grade of "S" and the only acceptable grade for COSC 998 (Dissertation Defense) is "P/F" (Pass/Fail).

B. Pursuing a Ph.D. after having completed an approved Master's Degree (36 Credits)

Core and Elective Courses (12 credits)

12 credit hours from the Core Courses. Select minimum four (4) courses from the following two knowledge areas:

Equitable AI

- COSC 502: Equitable Artificial Intelligence (3 credits)
- COSC 672: Emotional Reinforcement Learning (3 credits)
- COSC 680: Bias Detection in Image Understanding (3 creditsa0
- COSC 726: Explainability and Fairness in Machine Learning (3 credits)

Quantum Cryptography and Algorithms

- COSC 586: Quantum Computing (3 credits)
- COSC 614: Cryptography and Cryptology (3 credits)
- COSC 686: Quantum Algorithms and Architecture (3 credits)
- COSC 724: Post Quantum Cryptography (3 credits)

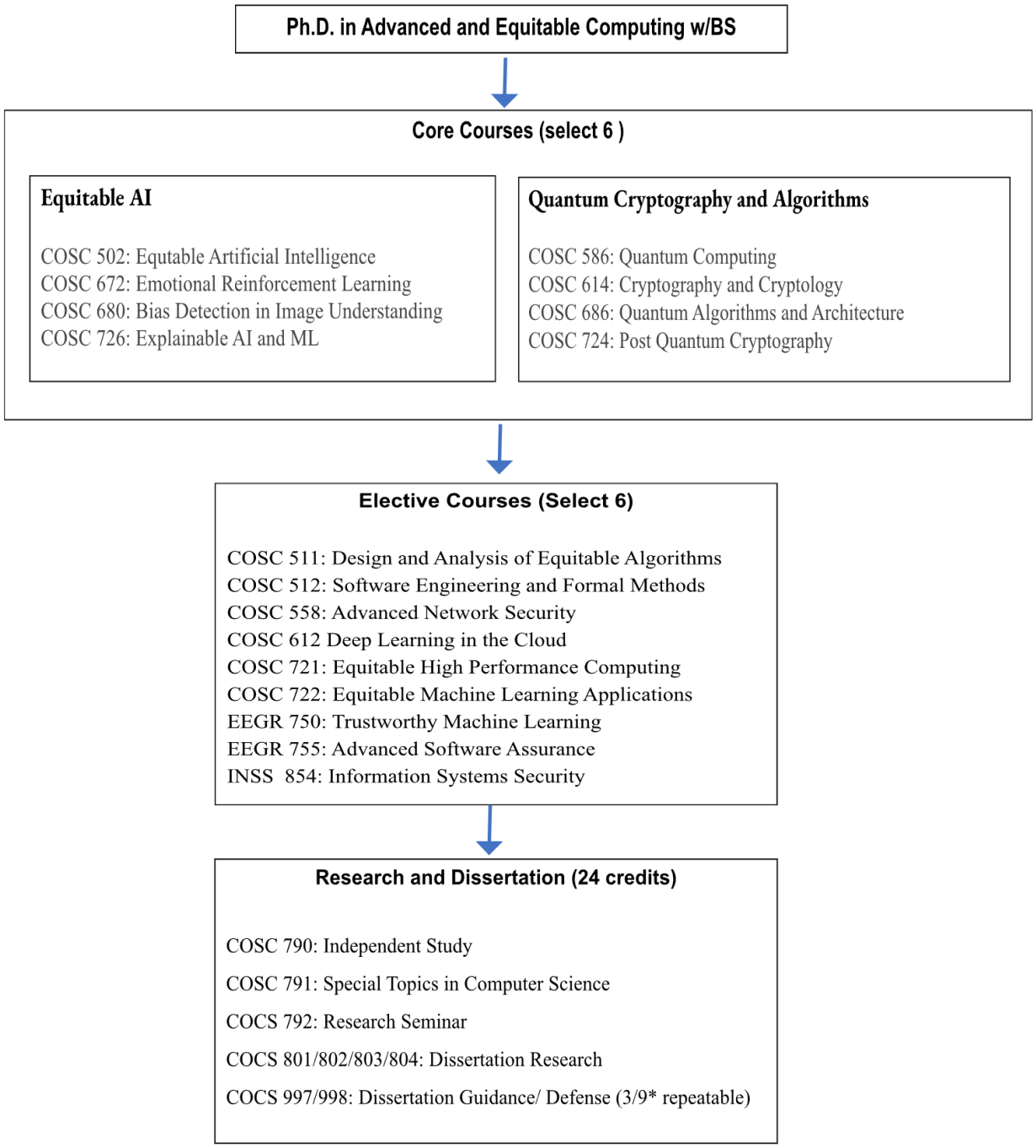
Other Courses

- COSC 511: Design and Analysis of Equitable Algorithms 3
- COSC 512: Software Engineering and Formal Methods 3
- COSC 558: Advanced Network Security 3
- COSC 612: Deep Learning in the Cloud 3
- COSC 711: Quantum Algorithms and Applications 3
- COSC 721: Equitable High-Performance Computing 3
- COSC 722: Equitable Machine Learning Applications 3
- EEGR 750: Trustworthy Machine Learning 3
- EEGR 755: Advanced Software Assurance 3
- INSS 854: Information Systems Security 3

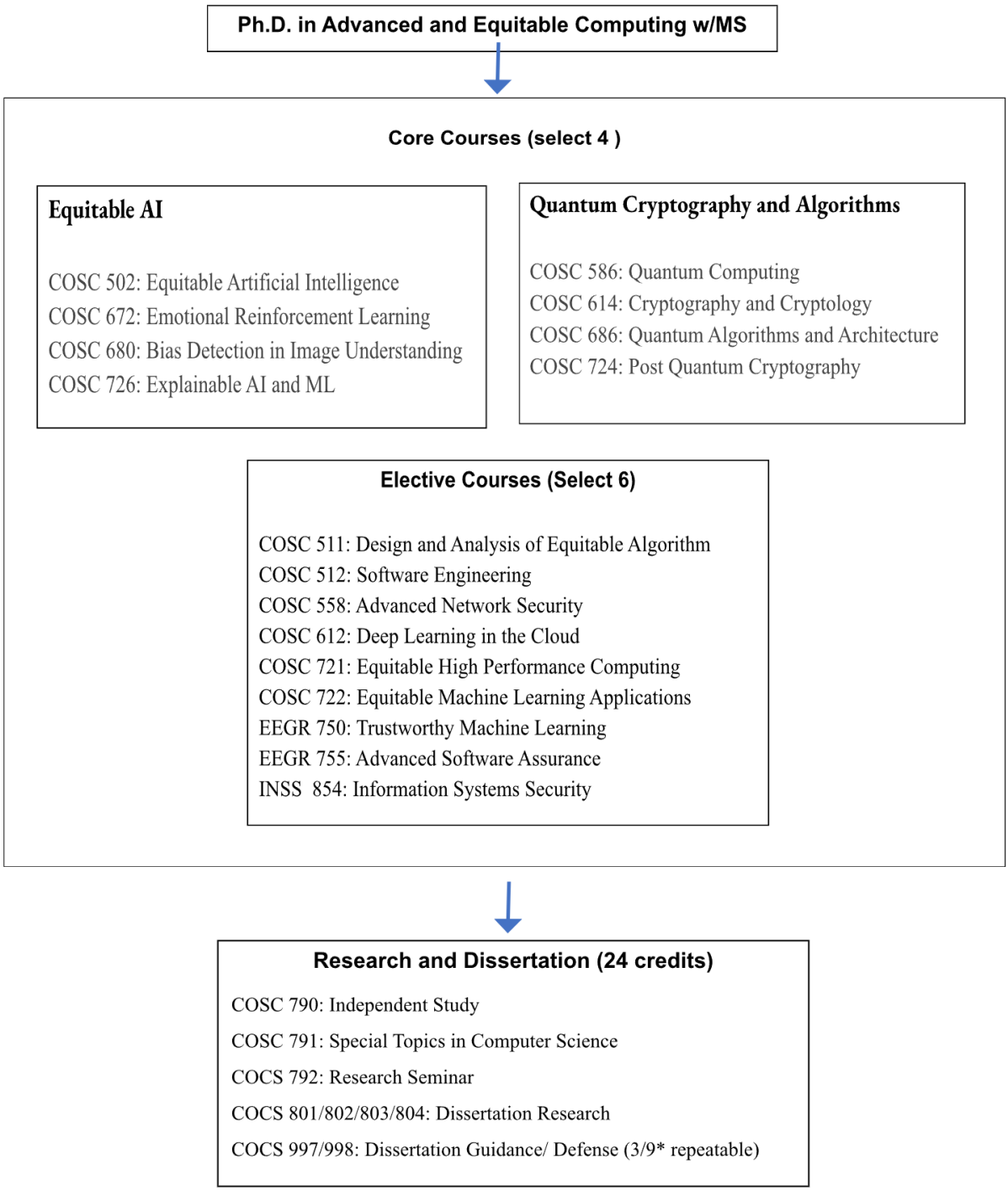
Dissertation Research Courses (24 credits)
The remaining **24 credits** will be for dissertation research where courses will be selected from following:

- COSC 790: Independent Study 3
- COSC 791: Special Topics in CS 3
- COSC 792: Research Seminar 3
- COSC 801: Dissertation Research I 3
- COSC 802: Dissertation Research II 3
- COSC 803: Dissertation Research III 3
- COSC 804: Dissertation Research IV 3
- COSC 997/998: Dissertation Guidance/Defense 3/9* credits, repeatable

Ph.D. Advanced and Equitable Computing Organogram (from a Bachelor's degree):



Ph.D. Advanced and Equitable Computing Organogram (from a Master's degree)



Course Descriptions

COSC 502: Equitable Artificial Intelligence [existing course]
Three hours lecture; 3 credits.
Prerequisites: none

This course covers a wide range of statistical models and equitable aspects in Data Science and advanced concepts of Artificial Intelligence needed to perform and implement intelligent agents/programs and to understand their applications. It focuses on the theory and algorithms underlying different AI and machine learning algorithms including heuristic approach and advanced search, inference in first-order logic, knowledge representation, meta-heuristic, hyper heuristics, probabilistic reasoning, machine learning and decision trees, Bayesian belief network, Robot control and motion planning. Students will learn TensorFlow and use it to work on a project.

COSC 511: Design and Analysis of Algorithms [existing course]
Three hours lecture; 3 credits.
Prerequisites: None

This course presents advanced concepts of algorithm design and methods of algorithm analysis. Algorithm design focuses on solving complex computational and real-world problems while the Algorithm analysis focuses on determining algorithm complexities (both time and space), completeness and correctness proof, comparisons among available solutions, and efficient decision making.

COSC 512: Software Engineering and Formal Method [existing course]
Three hours lecture; 3 credits.
Prerequisites: None

This course introduces components broadly covering the fundamentals of modern equitable software engineering according to software development life cycle (SDLC) and formal methods with learning by doing. The course will also cover need analysis, team collaboration, risk mitigation, budget constraints, and post deployment services.

COSC 558: Advanced Network Security [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 551

This course focuses on the protocols, skills and tools needed to support the development and delivery of advanced network and cloud services over the Internet. This graduate-level course is also focused on mastering technical details in a number of areas of advanced networking through reading and hands-on activities of important research topics in the field. The topics covered in this course include 1) network and cloud basics; 2) protocols; 3) network and cloud security; 4) mobile computing; 5) software-defined networking; 6) network and cloud management; 7) datacenter management; 8) big data analytics and cloud.

COSC 586: Quantum Computing [existing course]
Three hours lecture; 3 credits.
Prerequisites: none

This course introduces the theory and practice of quantum computing and the equitable aspect of quantum computing. Topics covered include: the basics of quantum computing, math, quantum theory, quantum architecture, and equitable quantum programming, Qiskit, intro to well-known quantum algorithms, QML, quantum machine learning, and quantum drug discovery.

COSC 612: Deep Learning in the Cloud
Three hours lecture; 3 credits.
Prerequisites: COSC 502

This course presents advanced concepts of Deep Learning with the focus on deep learning architecture. These concepts are needed to perform and implement advanced machine learning algorithms. It focuses on the theory and algorithms underlying different machine learning algorithms including Artificial Neural Network (ANN), Kernel methods, and ensemble methods. It also provides the theory and algorithms underlying different deep learning architecture including convolutional, recurrent, bidirectional neural networks. Students will work on a hands-on project using AWS SageMaker.

COSC 614: Cryptology and Cryptography [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 502

This course explores modern cryptographic (code making) and cryptanalytic (code breaking) techniques in detail. Topics covered include cryptographic primitives such as symmetric encryption, public key encryption, digital signatures, and message authentication codes, cryptographic protocols, such as key exchange, remote user authentication, side-channel attacks, replay attacks, power analysis, and quantum cryptography.

COSC 672: Emotional Reinforcement Learning [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 472

Emotional Reinforcement learning methodologies are critical to the sector of artificial intelligence requiring autonomous systems capable of making independent decisions. Deep learning environments relevant to robotics, game playing, and intelligent vehicles can be phrased in the context of reinforcement learning. This class will provide a thorough treatment of the theory behind reinforcement learning with a focus on emotion, and, additionally, will survey recent developments in emotional reinforcement learning research. Lecture materials will be supplemented with coding and research projects designed to explore reinforcement learning applications.

COSC 680: Bias Detection in Image Understanding [existing course, pending title change]
Three hours lecture; 3 credits.

Prerequisites: COSC 502

This course presents fundamental concepts of digital image processing and computer vision, and major approaches that address them. It covers a range of topics, starting from the basics of image formation and processing, feature extraction and representation, image classification, scene understanding, image segmentation and object detection using recent deep learning techniques in Python with OpenCV, scikit-learn, keras and TensorFlow libraries. With a specific focus on emotional intelligence, it will also cover project-based learning in real-time and multimodal (text, image, audio, etc.) emotion analysis.

COSC 686: Quantum Algorithms and Architecture [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 586

Quantum computation involves highly parallel systems devoted toward solving problems considered to be computationally difficult for classical computers. In this course, various quantum architectures and algorithms relevant to the theory of computation will be explored. Key results such as Grover's algorithm, quantum phase estimation and Shor's algorithm will be reviewed in order to provide context for the course. Quantum algorithms for solving linear equations and optimization problems will be introduced. Coding applications and current research involving quantum image processing and machine learning will be emphasized.

COSC 711 Quantum Algorithms and Applications [existing course, pending title change]
Three hours lecture; 3 credits.
Prerequisites: COSC 586

This course covers the study of quantum algorithms in speeding up the execution, optimization, equity, and solving Hamiltonian functions using classical and quantum hybrid approach. Strong numerical analysis, Fourier transform including QFT, algorithms, and programming skills are essential.

COSC 721: Equitable High-Performance Computing [existing course, pending title change]
Three hours lecture; 3 credits.
Prerequisites: COSC 502

This course will focus on equitable computing and discuss advanced topics of parallel systems covering topics ranging from what an HPC cluster consists of to how to efficiently solve complex large-scale problems in the areas of computational fluid dynamics, image processing, machine learning and analytics on these systems.

COSC 722: Equitable Machine Learning Applications [existing course, pending title change]
Three hours lecture; 3 credits.
Prerequisites: COSC 672

The course is to study ethical and equitable aspects of machine learning and their applications. It is a subfield of Artificial Intelligence and intersects with statistics, cognitive science, information

theory, and probability theory, among others. The course will explain how to build systems that learn and adapt using examples from real-world applications.

The class has a review session on probability and information theory to precede those chapters in need of background knowledge. Main topics include linear discriminants, neural networks, decision trees, support vector machines, unsupervised learning, reinforcement learning, and their applications.

COSC 724: Post Quantum Cryptography [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 586

The course will study the foundations of quantum computing and the important role of quantum computers in cryptography. It covers the post quantum cryptography algorithms, speedups offered by quantum algorithms, attacks on cryptography using quantum computers, design of cryptosystems resilient to quantum attacks and cryptographic protocols using quantum physics, such as quantum key distribution, quantum money, and next generation quantum Internet.

COSC 726: Explainability and Fairness in Machine Learning [Approval in Progress]

The machine learning models that power AI systems are often black boxes. Explainability is the ability to explain how or why a model makes a prediction. This graduate level course aims to familiarize students with the recent advances in the emerging field of eXplainable Artificial Intelligence (XAI). It covers different classes of interpretable models and post hoc explanations (e.g., rule-based and prototype-based models, feature attributions, counterfactual explanations, mechanistic interpretability). Since predictive models began making important decisions, from college admission to loan decisions, it becomes paramount to keep models from making unfair predictions. This course also explores fundamental issues and concepts of fairness and bias in machine learning, and shows how different metrics can be used to address these problems.

COSC 790: Independent Study [existing course]
Three Hours: 3 credits.
Prerequisites: Program director/chair approval

This course offers a study-related course which is approved by the faculty/adviser but carried out independently by students.

COSC 791: Special Topics in CS [existing course]
Three hours lecture; 3 credits.
Prerequisites: None

The Special Topics course covers various state-of-the-art topics in Computer Science and related areas. This may lead to developing/incorporating new/advanced courses in the Computer Science Department.

COSC 792: Research Seminar [existing course, cross-list with COSC 692]

Three Hours: 3 credits.
Prerequisites: Program director/chair approval

This Research Seminar is the foundation, preliminary study, and preliminary work toward Dissertation Guidance/Dissertation Defense.

EEGR 750 Trustworthy Machine Learning [existing course]
Three Hours: 3 credits.
Prerequisites: EEGR 580

The course covers different topics in emerging research areas related to the broader study of security and privacy in machine learning. Students will learn about attacks against computer systems leveraging machine learning, as well as defense techniques to mitigate such attacks. The class helps students explore new research directions and application. Most of the course readings will come from both seminal and recent papers in the field. Design projects are an integral part of this course.

COSC 801: Dissertation Research I [existing course]
Three Hours: 3 Credits
Prerequisite: None
Candidates conduct research under the supervision of the thesis adviser. Topics include literature review, methodology, technical writing, computer ethics, research and development, experiments, analysis and presentation, etc.

COSC 802: Dissertation Research II [existing course]
Three Hours: 3 Credits
Prerequisite: COSC 801
Candidates continue doing research guided by the thesis adviser. Topics include literature review, methodology, technical writing, computer ethics, research and development, experiments, analysis and presentation, etc.

COSC 803: Dissertation Research III [existing course]
Three Hours: 3 Credits
Prerequisite: COSC 802
Candidates continue doing research guided by the thesis adviser. Topics include literature review, methodology, technical writing, computer ethics, research and development, experiments, analysis and presentation, etc.

COSC 804: Dissertation Research IV [existing course]
Three Hours: 3 Credits
Prerequisite: COSC 803
Candidates continue doing research guided by the thesis adviser. Topics include literature review, methodology, technical writing, computer ethics, research and development, experiments, analysis and presentation, etc.

COSC 993: Pre-doctoral Candidacy [existing course]

Three Hours: 3 Credits (Reports as 9)
Prerequisites: Program director/chair approval

This course conveys full-time status to a doctoral student as a full-time student engaged in study prior to the achievement of doctoral candidacy. Students studying for comprehensive examinations or preparing for a proposal defense enroll in this course. This course is a non-curricular course and cannot be used as a program credit requirement. The student registers for 3 credit hours and the registration reports the full-time status of 9 graduate credit hours.

COSC 997: Dissertation Guidance [existing course]
Three Hours: Hours: 3 Credits (Reports as 9)
Prerequisites: Program director/chair approval

This course enables a student to develop and execute an approved scholarly research agenda in consultation with the student's dissertation chairperson and committee. Students must register for this course continuously to maintain enrollment until the student has completed the dissertation. This course is a non-curricular course and is not considered as part of the overall program credit requirement. However, this course maintains the student's status as a matriculated, full-time student (student registers for 3 credit hours each semester but is acknowledged as having a 9 credit hours load).

COSC 998 Dissertation Defense [existing course]
Three Hours: 3 Credits (Reports as 9)
Prerequisites: Program director/chair approval

This course allows students the opportunity to defend their dissertation for approval by the student's dissertation chairperson and committee after the dissertation has been completed. After gaining approval of the dissertation chairperson and committee, the dissertation is submitted to the School of Graduate Studies for final processing and approval. This course is a curricular course and may be considered as 3 credit hours of the overall program credit requirement. This course maintains the student's status as a matriculated, full-time student (student is registered for 3 credit hours but is acknowledged as having a 9 credit hours load).

5. ***Discuss how general education requirements will be met, if applicable.***
6. ***Identify any specialized accreditation or graduate certification requirements for this program and its students.***
7. ***If contracting with another institution or non-collegiate organization, provide a copy of the written contract.***

   Items 5-7 are not applicable.

8. ***Provide assurance and any appropriate evidence that the proposed program will provide students with clear, complete, and timely information on the curriculum, course and degree requirements, nature of faculty/student interaction, assumptions about technology competence and skills, technical equipment requirements, learning management system, availability of academic support services and financial aid resources, and costs and payment policies.***

- **Guidance to students on Curriculum, Course, & Degree Requirements.** Morgan State University uses DegreeWorks for all programs. As such, students can always evaluate the entire curriculum, know how they are progressing toward completion of the program, and know when they are finished. The system provides up to date information regarding all courses, grades, and requirements.
- **Nature of Faculty/Student Interaction.** MSU has an established student handbook describing the nature of faculty/student interactions. Furthermore, the SCMNS established a set of online documents to facilitate communication between graduate students and faculty members for various tasks, including the selection of research supervisor and dissertation committee members. Graduate program directors provide students with additional information in periodic meetings on the etiquette of interactions with faculty members. The Graduate School organizes periodic Gradlife workshops to train students on these interactions as well. In addition, faculty and students are expected to interact regularly within classes, during office hours, in advising sessions, and in laboratory work. The Canvas Learning Management System (LMS) can also facilitate additional interactions that may include e-mail communication, graded feedback and response to feedback, Zoom/Big Blue Button remote engagement, and other technologies that allow for pre-recorded content with additional faculty communication which students can access at will.
- **Acclimation to Technology & Services.** Through the Office of Academic Technology Services (https://www.morgan.edu/ats), students, faculty, and staff are provided with online training as well as live workshop opportunities on the various technologies utilized across campus for academic instruction. The syllabi for each course will contain information on the required technology and services expected for learners, as well as resources for students who need help using the technologies required.
- **Academic Support Services.** Morgan State subscribes to learner resources as a component of the Canvas LMS. The Office of Student Disability Services is available to provide additional resources for learners, including test proctoring when needed.
- **Financial Aid Resources.** The graduate program director will meet with all students at least twice a year to discuss and to evaluate their academic progress. Research supervisors will also provide academic support to graduate students in the program. The Office of Financial Aid provides a listing of resources for students (https://www.morgan.edu/office-of-financial-aid/resources) and has staff available in Tyler Hall five days a week.
- **Cost & Payment Policies.** Information on tuition and fees and other matters of billing is handled by the Office of the Bursar which has information about payment plans and billing schedules on its website (https://www.morgan.edu/bursar).

9. Provide assurance and any appropriate evidence that advertising, recruiting, and admissions materials will clearly and accurately represent the proposed program and the services available.

The Program Director, along with the Chief Academic Officer (i.e., Provost) and the University's Registrar, will ensure that the proposed program and services are accurately represented to potential and current learners.

H. Adequacy of Articulation

1. If applicable, discuss how the program supports articulation with programs at partner institutions.

Not applicable. There are no articulation agreements in place.

I. Adequacy of Faculty Resources (as outlined in COMAR 13B.02.03.11)

1. Provide a brief narrative demonstrating the quality of program faculty. Include a summary list of faculties with appointment type, terminal degree title and field, academic title/rank, status (full-time, part-time, adjunct) and the course(s) each faculty member will teach.

MSU has distinguished faculty members in the School of Computer, Mathematical and Natural Sciences, and specifically at the Department of Computer Science who have the background and expertise to deliver the MS program in Advanced Computing. The Department of Computer Science will administer this program through a full-time program director at MSU. The computer science department currently has 15 full-time tenure faculty, 4 full-time lectures, and 1 staff. The equitable AI center (CEAMLS) has 14 tenure-track faculty positions including the four recently recruited CS faculty.

In addition, the Department of Computer Science at MSU has recently initiated a collaboration with Google and Facebook to train high-skill students in computer science to promote diversity in large high-tech companies. These companies have agreed to provide this department with trainers, facilities, and equipment to develop its infrastructure to attain this objective. Also, the department of computer science in collaboration with Google started a program in Silicon Valley to train students from underrepresented communities and prepare them with skills and expertise to be recruited in this company. In addition, Google offers over 30 students at MSU to undertake internships at this institute to promote motivation among underrepresented communities to obtain necessary skills to join this company.

Table of PhD in Advanced and Equitable Computing program faculty positions, including those to be hired and the members of the program faculty committee, who will support the teaching mission of this program. All faculties for this program will have terminal degrees.

Computer Science Faculty	
Dr. Shuangbao Wang	Professor and chair, Department of Computer Science
full-time faculty	PhD Computer Science, COSC 614, 711, quantum crypto
Dr. Mohamed Eltoweissy	Professor, Department of Computer Science
full-time faculty	PhD Computer Science, COSC 721, cybersecurity
Dr. Md Rahman	Associate Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 502, 680, equitable AI

Dr. Vojislav Stojkovic	Associate Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 611, 612, equitable AI
Dr. Eric Sakk	Associate Professor, Computer Science
full-time faculty	PhD ECE, COSC 686, 723, quantum computing, cryptography
Dr. Edward Dillon	Associate Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 638, 792
Dr. Radhouane Chouchane	Associate Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 504, 513
Dr. Timothy Oladunni	Associate Professor, Computer Science
full-time faculty	PhD Computer Science, COC672, AI/ML
Dr. Guobin Xu	Associate Professor, Computer Science
full-time faculty	PhD Information Science, COC 558, 721, 724, quantum IoT
Dr. Monireh Dabaghchian	Assistant Professor, Computer Science
full-time faculty	PhD ECE, COSC 551, 558, cybersecurity
Dr. Naja Mack	Assistant Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 722, equitable AI
Dr. Amjad Ali	Professor, Computer Science
full-time faculty	PhD Engineering, COSC 790, cybersecurity
Dr. Jamell Dacon	Assistant Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 672, equitable AI
Vahid Heydari	Associate Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 722, cybersecurity, IoT
Blessing Ojeme	Assistant Professor, Computer Science
full-time faculty	PhD Computer Science, COSC 672, equitable AI
Dr. Monir Sharker	Associate Professor, Computer Science
Adjunct faculty	PhD Computer Science, COSC 612
Dr. Roshan Paudel	Professor of Practice, Computer Science
full-time faculty	PhD Bioinformatics, program support staff
Dr. Jin Guo	Professor of Practice, Computer Science
full-time faculty	PhD Computer Science COSC 512, 790
Dr. Sam Tannouri	Lecturer, Computer Science
full-time faculty	PhD Computer Science, qualifying exam and candidacy exam
Ms. Grace Steele	Lecturer, Computer Science
full-time faculty	Program support staff
Other Faculty (Faculty at CEAMLS, ECE, and ISS)	
Dr. Michael Spencer	Professor ECE, quantum computing
Dr. Cliston Cole	Assistant Professor ECE, cybersecurity

Dr. Arlene Cole-Rhodes	Associate Professor ECE, IoT, cybersecurity
Dr. Mahmi Khalifa	Assistant Professor ECE, Equitable AI
Dr. Kevin Kornegay	Professor ECE, cybersecurity
Dr. Kofi Nyarko	Professor ECE, Director of CEAMLS, equitable AI
Dr. Onyema Osuagwu	Associate Professor ECE, cybersecurity
Dr. Zheng Li	Assistant Professor Mechatronics, quantum computing
Dr. Jigish Zaveri	Professor ISS, AI, security
Dr. Sanjay Bapna	Professor ISS, AI, security, data analytics
Dr. Mary Dunaway	Assistant Professor ISS, AI
Dr. Samuel Ejiaku	Associate Professor ISS, risk analysis
Dr. Shirin Hasavari	Assistant Professor ISS, AI/ML, digital twin
Dr. Farzad Moazzami	Associate Professor ISS, cryptography
Dr. Thomas Ngniatedema	Associate Professor ISS, AI

In addition, the computer science department has the support of the University's President, Provost, and the Dean (SCMNS) to repurpose current vacant salary lines with SCMNS.

1. ***Demonstrate how the institution will provide ongoing pedagogy training for faculty in evidence-based best practices including training in:***

a) pedagogy that meets the needs of the students,

As Morgan State's Director of the Center for Innovative Instruction & Scholarship (CIIS) is charged with leading the campus efforts to assist all instructors in matters of pedagogy. The Center's Director maintains a Canvas course page with additional resources to complement the in-person workshops, Zoom sessions, and individual meetings based on the scholarship on teaching and learning that undergird the creation of innovative and active learning environments.

b) the learning management system,

As The campus learning management system (LMS) is Canvas. A Canvas Administrator hosts technical training on the use of Canvas and maintains a Canvas course page with additional resources to guide faculty and students (currently Ms. Heather Laird).

c) evidenced-based best practices for distance education, if distance education is offered

As The Director of Morgan Online oversees the review of online courses at Morgan, and the training of faculty and teaching assistants through either Quality Matters or Morgan's Teach Online (in conjunction with the Canvas Administrator). The director is also responsible for assuring that the C-RAC guidelines are followed.

MSU requires all faculty teaching in online courses (whether synchronous remote or asynchronous online) to either have completed Quality Matters Teach Online Training or Morgan's Teach Online Training which is instructed by Morgan's Canvas Administrator (currently, Ms. Heather Laird) or provide evidence of the equivalent credentials if hired as contractual faculty. Contractual faculty may also complete the training at Morgan before the start of classes for eligibility to teach online or remote sections. Additional training in best practices related to both in-class and online pedagogy is available through Morgan's Center for Innovative Instruction & Scholarship (CIIS) which hosts workshops, offers individual training sessions, and maintains a repository of materials relevant to teaching excellence. These are offered by the Director of the Center (currently, Dr. Laura DorseyElson). Courses offered online must meet the standards and requirements of Quality Matters and are evaluated by qualified course evaluators under the direction of the Director of Morgan Online (currently, Dr. Cynthia Brown-Laveist).

J. Adequacy of Library Resources (as outlined in COMAR 13B.02.03.12)

J.1. MSU Library[3]

1. ***Describe the library resources available and/or the measures to be taken to ensure resources are adequate to support the proposed program***

The students will have access to MSU Earl S. Richardson Library (MSU Library). MSU Library offers a range of resources and services to the MSU community. The library has IEEE, ACM and other common Computer Science area full-text databases and journals. Most library resources (USMAI Catalog, WorldCat MSU, Libguides, Collections, etc.) and services can be accessed remotely.

In addition, the director of Earl S. Richardson Library, Dr. Richard Bradberry, has affirmed that the library resources will be provided to MS program in Advanced Computing Program in addition to providing additional required materials such as books and journals on: Software Engineering, Data Science, Data Mining, Data Science Tools, Visualization, Image Processing, Pattern Recognition, Machine Learning, Statistical Programming, High Performance Computing, etc.

K. Adequacy of Physical Facilities, Infrastructure, and Instruction Equipment (as outlined in COMAR 13B.02.03.13)

K.1. Physical Facilities: No extra facilities other than the existing are required.

1. ***Provide an assurance that physical facilities, infrastructure, and instruction equipment are adequate to initiate the program, particularly as related to spaces for classrooms, staff and faculty offices, and laboratories for studies in the technologies and sciences.***

The four to six floors of the McMechen building are being renovated and the Computer Science

[3] http://www.morgan.edu/library

department will occupy the space. There are twelve office spaces on the fifth and sixth floors with the Department office, and classroom and research spaces on the fourth floors. In addition, more space in Calloway Hall will be retained and assigned to the computer science department.

K.2. Infrastructure Equipment: The program does not need additional infrastructure equipment.

K.3. Instruction Equipment:

MSU has comparable research facilities to that of other higher education institutions in the State of Maryland and/or region. School of Computer Mathematical and Natural Science facilities include many research and study labs in Biology, Medical Technology, Chemistry, Computer Science (Robotics, Bioinformatics, Computer, Machine learning, Network, and Cyber Security), Mathematics, Physics, etc. MSU has licenses for widely used software for analytics such as SAS, and JMP Pro. plus MATLAB, etc.

The Equitable AI Laboratory is in Calloway Hall, Room 304. It has 20 PCs connected in a network. Each computer has specific computing platforms installed, and Windows and Linux Operating Systems are available. The laboratory has a variety of software for bias detection, ML model training, and remote access to high performance computing systems. The laboratory also has a great collection of programming languages such as C, C++, Java, C#, Microsoft Visual Programming Language, MATLAB, Mathematica, Perl, etc.

The Robotics, Cloud Computing and Cybersecurity Laboratory is being established in Calloway Hall. We plan to have Drones, AWS IoT buttons, DeepLens, DeepRacer, and Siemens PLC 1200 for students to gain hands-on experiences. In addition, students can access the NICE Challenge lab, a virtual lab for students to build work experience before the workforce.

The Quantum Cryptography lab has the world class quantum key distribution devices and single photon generation and detection for research and quantum education (cost over $250k). The ID Quantiqe QKD device sits in McMechen 519, used for research by the Morgan Quantum Computing group in the computer science department.

2. Provide assurance and any appropriate evidence that the institution will ensure students enrolled in and faculty teaching in distance education will have adequate access to:

a) an institutional electronic mailing system.

As Morgan State University utilizes a branded email system through Google Workspace. All Morgan students are assigned a student email address and login credentials upon admission. All faculty are assigned a faculty email address and login credentials upon hire. Access to the University's electronic mailing system is extremely flexible and universal.

b) a learning management system that provides the necessary technological support for distance education.

MSU currently offers courses online via its Canvas platform learning management system.

In addition, students will have access to library resources online. The library houses many educational resources, books, journals, articles, pamphlets, etc. With the university ID number, students and faculty can access all library resources by visiting the website. In addition, the library building houses computing services with competent full-time staff for direct service to faculty and students. Once enrolled, all Morgan students have access. This system works to support distance education as it provides the following:

- A repository for all course materials for all courses at Morgan State University;
- The same platform used by all students regardless of the instructional modality of the course;
- Easy connection and integration to other digital tools provided by Morgan State University;
- Canvas and its tools work equally well supporting synchronous and asynchronous online classes, as well as facilitating the management of face-to-face courses.

L. Adequacy of Financial Resources with Documentation (as outlined in COMAR 13.B.02.03.14)

1. Resource Allocation

1. ***Complete Table 1: Resources and Narrative Rationale.***
   Provide finance data for the first five years of program implementation. Enter figures into each cell and provide a total for each year. Also, provide a narrative rationale for each resource category. If resources have been or will be reallocated to support the proposed program, briefly discuss the sources of those funds.

1.1. Resource Allocation Table

TABLE 1: RESOURCES					
Resource Categories	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
1. Reallocated Funds	0	0	0	0	0
2. Tuition/Fee Revenue (c+g)	90,475	180,950	271,425	361,900	402,375
a. Number of F/T Students	5	10	15	20	25
b. Annual Tuition/Fee Rate	18,095	18,095	18,095	18,095	16,095
c. Total F/T Revenue (a*b)	90,475	180,950	271,425	361,900	402,375
d. Number of P/T Students	0	0	0	0	0
e. Credit Hour Rate	536.5	536.5	536.5	536.5	536.5
f. Annual Credit Hour Rate	0	0	0	0	0
g. Total P/T Revenue (d*e*f)	0	0	0	0	0
3. Grants, Contracts, and Other External Sources	0	0	0	0	0
4. Other Sources	130,000	195,000	260,000	320,000	390,000
Total (Add 1-4)	220,475	375,950	531,425	681,900	792,375

1.2. Resource Allocation Justification

1. Reallocated Funds. Program does not have reallocated funds.

2. Tuition/Fee Revenue. We project the program will have five full-time equivalent (FTE) students in the first year and ten in the second year, and five more students increase in subsequent years. Part-time students are factored into the FTE. The estimated revenue is based on each student taking a full load of twelve credit hours (12) per semester and six credit hours during the summer, and a tuition and fees rate of $545.50/credit for in-state students (2024-2025 tuition and fee schedule).

3. Grants, Contracts, and Other External Sources: None at this time.

4. Other Sources: No other sources.

2. Expenditures

2. Complete Table 2: Program Expenditures and Narrative Rationale.

Provide finance data for the first five years of program implementation. Enter figures into each cell and provide a total for each year. Also, provide a narrative rationale for each expenditure category.

2.1. Expenditures Table

TABLE 2: EXPENDITURES					
Expenditure Categories	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**
1. Faculty (b+c)	0	0	170,400	175,512	0
a. # FTE	0	0	1	1	0
b. Total Salary	0	0	120,000	123,600	0
c. Total Benefits	0	0	50,400	51,912	0
2. Administrative Staff (b+c)	0	0	0	0	0
a. # FTE	0	0	0	0	0
b. Total Salary	0	0	0	0	0
c. Total Benefits	0	0	0	0	0
3. Support Staff (b+c)	0	0	0	0	0
a. # FTE	0	0	0	0	0
b. Total Salary	0	0	0	0	0
c. Total Benefits	0	0	0	0	0
4. Equipment	100,000	100,000	0	0	0
5. Library	0	0	0	0	0
6. New or Renovated Space	0	0	0	0	0
7. Other Expenses	5,000	5,000	5,000	5,000	5,000
TOTAL (Add 1–7)	105,000	105,000	175,400	180,512	5,000

2.2. Expenses Justification

All expenses here are expected from program-generated revenues.

1. Faculty: One faculty who will be acting as the Program Coordinator will be assigned to a current faculty. The department is adding four new faculty positions (already budgeted). A faculty member for the third year of the program (under an assumption that target enrollments are in line with expectations) will be expected to oversee the recruitment, admission, advising, and student matriculation through the program and a second faculty member will be recruited in the fourth year in one of the specialty areas of Artificial Intelligence, Data Science, Software Engineering, etc. Benefits calculated at 42% of salary. Growth rate used for salary calculations = 2% to adjust for cost of living increases.
2. No notes.
3. No notes.
4. Equipment: Necessary AI/ML, computational, visualization, and cybersecurity equipment will be purchased in years one and two ($100,000).
5. No notes.
6. No notes.
7. Other Expenses: Lab and students' support fees, $5,000 each year. This cost is not expected to come from new state appropriations but should come from program-generated revenues.

M. Adequacy of Provisions for Evaluation of Program (as outlined in COMAR 13B.02.03.15)

1. ***Discuss procedures for evaluating courses, faculty, and student learning outcomes***
2. ***Explain how the institution will evaluate the proposed program's educational effectiveness, including assessments of student learning outcomes, student retention, student and faculty satisfaction, and cost-effectiveness***

The courses, the program's effectiveness, enrollment, retention and graduation rates, students, instructors, and staff satisfaction will be evaluated using student, faculty, and staff surveys and program committee reviews on a regular basis.

The program faculty will meet each semester for assessment and evaluation of the curriculum. The program committee will meet annually for assessment and evaluation of the program. By needs, the program committee will implement changes to the program.

The program will be subject to external review and evaluation for accreditation by Middle States.

N. Consistency with the State's Minority Student Achievement Goals (as outlined in COMAR 13B.02.03.05 and in the State Plan for Postsecondary Education)

1. ***Discuss how the proposed program addresses minority student access & success, and the institution's cultural diversity goals and initiatives***

The State of Maryland has set as its goals for minority achievement implementing policies (Minority Achievement Report Summary, Maryland Community Colleges, University of Maryland System, Morgan, St. Mary's College of Maryland, October 1996) to improve

recruitment, retention, and graduation of students, particularly minorities and to recruit, promote and retain minorities in faculty and professional staff positions. The proposed MS in Advanced Computing program is aimed at the first of those two goals. By providing an easier path toward graduation for nontraditional students, it should significantly increase its retention and graduation rates.

O. Relationship to Low Productivity Programs Identified by the Commission

1. If the proposed program is directly related to an identified low-productivity program, discuss how the fiscal resources (including faculty, administration, library resources, and general operating expenses) may be redistributed to this program.

There is no relationship with low-productivity programs identified by the Commission.

P. If proposing a distance education program, please provide evidence of the Principles of Good Practice (as outlined in COMAR 13B.02.03.22C)

1. Provide affirmation and any appropriate evidence that the institution is eligible to provide distance education

Morgan is an active SARA institution (see NC-Sara Directory| NC-SARA).

2. Provide assurance and any appropriate evidence that the institution complies with the C-RAC guidelines, particularly as it relates to the proposed program

As a SARA institution, MSU has agreed to abide by C-RAC Guidelines.

The Ph.D. in Advanced and Equitable Computing will be offered in both online and onsite formats.

Morgan is experienced and with adequate infrastructure to support online programs. Morgan Online, **https://www.morgan.edu/online**, established several years ago, was created to help launch various online degree programs. Currently, Morgan has the following active onsite/online programs:

- MS in Advanced Computing, 42 students, 8 graduates. 2020-2024
- Community College Leadership Program (Ed.D.), 15 graduates in 2020-2022
- Master's of Business Administration (MBA), 19 graduates in 2020-2022
- Master of Social Work (MSW), 56 graduates in 2020-2022
- MS in Project Management (MSPM), 7 graduates in 2020-2022
- Post-Baccalaureate Certificate in Project Management

- Post-Baccalaureate Certificate in Sustainable Urban Communities

In the past two years (2020-2022) alone, MSU graduated 15 doctoral and 82 Master's students through its online degree programs.

[End]

Appendix A. Course comparisons between the proposed program and courses offered at selected other Maryland institutions.

Course Comparison with CS PhD Program at UMBC

Existing Courses – Proposed Program	Courses at UMBC
COSC 502: Equitable Artificial Intelligence (3 credits – Lecture) This course covers a wide range of statistical models and equitable aspects in Data Science and advanced concepts of Artificial Intelligence needed to perform and implement intelligent agents/programs and to understand their applications. It focuses on the theory and algorithms underlying different AI and machine learning algorithm including heuristic approach and advanced search, inference in first order logic, knowledge representation, meta heuristic, hyper heuristics, probabilistic reasoning, machine learning and decision trees, Bayesian belief network, Robot control and motion planning. Students will learn TensorFlow and use it to work on a project. Prerequisites: none.	**CMSC 671 - Principles of Artificial Intelligence** (3 credits – Lecture) This course will serve as an introduction to Artificial intelligence concepts and techniques. We will use Python as a computational vehicle for exploring the techniques and their application. Specific topics we will cover include the history and philosophy of AI, the agent paradigm in AI systems, search, game playing, knowledge representation and reasoning, logical reasoning, uncertain reasoning and Bayes nets, planning, machine learning, and multi-agent systems, robotics, and natural language processing. If time permits, we may also briefly touch on functional programming, perception, and knowledge representation and reasoning. Prerequisite: CMSC 471.
COSC 512: Software Engineering Three hours lecture; 3 credits. Prerequisites: COSC 220 General survey of software engineering principles with topics on project planning and management, design techniques, verification and validation. It focuses on group projects in which groups of students implement a system from its specification. It also introduces software life cycle models. Techniques for software design and testing. Cost estimation models. Issues in software quality assurance and software maintenance.	None
COSC 672: Emotional Reinforcement Learning (3 credits – Lecture) Emotional Reinforcement learning methodologies are critical to the sector of artificial intelligence requiring autonomous systems capable of making independent decisions. Deep learning environments relevant to robotics, game playing, and intelligent vehicles can be phrased in the	None

context of reinforcement learning. This class will provide a thorough treatment of the theory behind reinforcement learning with a focus on emotion, and, additionally, will survey recent developments in emotional reinforcement learning research. Lecture materials will be supplemented with coding and research projects designed to explore reinforcement learning applications. Prerequisites: COSC 472 or COSC 502	
COSC 680: Bias in Image Understanding (3 credits – Lecture) This course presents fundamental concepts of digital image processing and computer vision, and major approaches that address them. It covers a range of topics, starting from the basics of image formation and processing, feature extraction and representation, image classification, scene understanding, image segmentation and object detection using recent deep learning techniques in Python with OpenCV, scikit-learn, keras and TensorFlow libraries. With a specific focus on emotional intelligence, it will also cover project-based learning in real time and multimodal (text, image, audio, etc.) emotion analysis. Prerequisites: COSC 502.	**CMSC 691 - Computer Vision** (3 credits - Lecture) This course will offer a comprehensive introduction to the field of computer vision which has the broad goal of understanding visual signals (images and videos) for low/mid/high-level perceptual tasks. This course will introduce fundamental principles and concepts for developing computer vision systems such as image formation, acquisition, and processing, stereo and 3D vision, machine learning algorithms and neural networks for image understanding. Prerequisite: None.
COSC 726: Explainability and Fairness in Machine Learning (3 credits – Lecture) The machine learning models that power AI systems are often black boxes. This graduate level course aims to familiarize students with the recent advances in the emerging field of eXplainable Artificial Intelligence (XAI). It covers different classes of interpretable models and post hoc explanations. This course also explores fundamental issues and concepts of fairness and bias in machine learning and shows how different metrics can be used to address these problems.	None
COSC 586: Quantum Computing (3 credits) This course introduces the theory and practice of quantum computing and the equitable aspect of quantum computing. Topics covered include: the basics of quantum computing, math, quantum theory, quantum architecture, and equitable	**CMSC 643: Quantum Computation** (3 credits - Lecture) The course begins with a brief overview of those topics in quantum mechanics and mathematics needed to understand quantum computation. It then will focus on quantum algorithms, covering such

quantum programming, Qiskit, intro to well-known quantum algorithms, QML, quantum machine learning, and quantum drug discovery. Prerequisite: None.	topics as quantum superposition and quantum entanglement, quantum decoherence, quantum teleportation, quantum Turing machines, Shor's algorithm, Grover's algorithm, Hallgren's algorithm, quantum information theory, quantum data compression, quantum cryptographic protocols, quantum error-correcting codes and implementation issues. Various research-level problems will be discussed. Prerequisite: CMSC 641, or CMSC 651
COSC 614: Cryptography and Cryptology (3 credits – Lecture) This course explores modern cryptographic (code making) and cryptanalytic (code breaking) techniques in detail. Topics covered include cryptographic primitives such as symmetric encryption, public key encryption, digital signatures, and message authentication codes, cryptographic protocols, such as key exchange, remote user authentication, side-channel attacks, replay attacks, power analysis, and quantum cryptography. Prerequisites: COSC 502.	**CMSC 652 - Cryptography and Data Security** (3 credits - Lecture) Conventional and public-key cryptography. Selected cryptosystems, including DES and RSA. Digital signatures, pseudo-random number generation, cryptographic protocols and cryptanalytic techniques. Applications of cryptography to e-commerce. Prerequisite: CMSC 441 and MATH 221.
COSC 686: Quantum Algorithms and Architecture (3 credits)	None
COSC 724: Post Quantum Cryptography (3 credits)	None
COSC 511: Design and Analysis of Equitable Algorithms (3 credits – Lecture) This course presents advanced concepts of algorithm design and methods of algorithm analysis. Algorithm design focuses on solving complex computational and real world problems while the Algorithm analysis focuses on determining algorithm complexities (both time and space), completeness and correctness proof, comparisons among available solutions, and efficient decision making. Prerequisites: None	**CMSC 641 - Design and Analysis of Algorithms** (3 credits - Lecture) A study of advanced topics and techniques in discrete algorithms. Assumes student has a solid preparation in undergraduate algorithms (including asymptotic notations, recurrences, divide-and-conquer, greedy algorithms, dynamic programming, and fundamental graph algorithms). Core topics include probabilistic and amortized analysis, network flow, NPcompleteness, and parallel algorithms. Selected topics might include: linear programming, computational geometry, randomized algorithms, cryptographic algorithms, and approximation algorithms. Prerequisite: CMSC-441 or equivalent.

COSC 558: Advanced Network Security (3 credits – Lecture) This course focuses on the protocols, skills and tools needed to support the development and delivery of advanced network and cloud services over the Internet. This graduate-level course is also focused on mastering technical details in a number of areas of advanced networking through reading and hands-on activities of important research topics in the field. The topics covered in this course include 1) network and cloud basics; 2) protocols; 3) network and cloud security; 4) mobile computing; 5) software-defined networking; 6) network and cloud management; 7) datacenter management; 8) big data analytics and cloud. Prerequisites: COSC 551.	**CMSC 687 - Introduction to Network Security** (3 credits – Lecture) The objective of this course is to teach the fundamental concepts, architectures and protocols related to network security. Topics covered include: overview of network security; basics of cryptography; threat models; authentication and authorization mechanisms and standards; public key infrastructure; electronic mail security; network layer security; transport layer and web security; packet filtering, firewalls, intrusion detection, and virtual private networks; recent topics in network security. Prerequisite: CMSC 341 and CMSC 481.
COSC 612: Deep Learning in the Cloud (3 credits – Lecture) This course introduces Deep Learning (DL), learning complex and hierarchical feature representations from raw data. Topics include: fundamental principles of DL, underlying mathematics, and implementation details of deep learning with an emphasis on practical implementation of applications through in-depth programming assignments. Prerequisite(s) COSC 502 Offered AS NEEDED	**IS 757: Deep Learning** This course is an introduction to deep learning, a subset of machine learning, concerned with the development and application of modern neural networks. In this course, students will learn about the theory and application of deep learning. We will cover a range of topics from basic Neural Networks, Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN), Generative Adversarial Networks (GAN), and deep unsupervised learning. Besides, the students will learn how to apply the deep learning methods to solve real-world problems in several areas including computer vision, remote sensing, medical, language, and AI for social good applications and develop the insight necessary to use the tools and techniques to solve any new real-world problem.
COSC 721: Equitable High Performance Computing (3 credits – Lecture) This course will focus on equitable computing and discuss advanced topics of parallel systems covering topics ranging from what an HPC cluster consists of to how to efficiently solve complex large-scale problems in the areas of computational fluid dynamics, image processing, machine learning and analytics on these systems. Prerequisites: COSC 502	None

COSC 722: Equitable Machine Learning Applications (3 credits – Lecture) The course is to study ethical and equitable aspects of machine learning and their applications. It is a subfield of Artificial Intelligence and intersects with statistics, cognitive science, information theory, and probability theory, among others. The course will explain how to build systems that learn and adapt using examples from real-world applications.	None

Course Comparison with IT PhD Program at Towson

Existing Courses – Proposed Program	Courses at Towson
COSC 502: Equitable Artificial Intelligence (3 credits – Lecture) This course covers a wide range of statistical models and equitable aspects in Data Science and advanced concepts of Artificial Intelligence needed to perform and implement intelligent agents/programs and to understand their applications. It focuses on the theory and algorithms underlying different AI and machine learning algorithm including heuristic approach and advanced search, inference in first order logic, knowledge representation, meta heuristic, hyper heuristics, probabilistic reasoning, machine learning and decision trees, Bayesian belief network, Robot control and motion planning. Students will learn TensorFlow and use it to work on a project. Prerequisites: none.	None
COSC 512: Software Engineering Three hours lecture; 3 credits. Prerequisites: COSC 220 General survey of software engineering principles with topics on project planning and management, design techniques, verification and validation. It focuses on group projects in which groups of students implement a system from its specification. It also introduces software life cycle models. Techniques for software design and testing. Cost estimation models. Issues in software quality assurance and software maintenance.	None
COSC 672: Emotional Reinforcement Learning (3 credits – Lecture) Emotional Reinforcement learning methodologies are critical to the sector of artificial intelligence requiring autonomous systems capable of making independent decisions. Deep learning environments relevant to robotics, game playing, and intelligent vehicles can be phrased in the context of reinforcement learning. This class will provide a thorough treatment of the theory behind	None

reinforcement learning with a focus on emotion, and, additionally, will survey recent developments in emotional reinforcement learning research. Lecture materials will be supplemented with coding and research projects designed to explore reinforcement learning applications. Prerequisites: COSC 502	
COSC 680: Bias Detection in Image Understanding (3 credits – Lecture) This course presents fundamental concepts of digital image processing and computer vision, and major approaches that address them. It covers a range of topics, starting from the basics of image formation and processing, feature extraction and representation, image classification, scene understanding, image segmentation and object detection using recent deep learning techniques in Python with OpenCV, scikit-learn, keras and TensorFlow libraries. With a specific focus on emotional intelligence, it will also cover project-based learning in real time and multimodal (text, image, audio, etc.) emotion analysis. Prerequisites: COSC 502.	**COSC 602: Computer Vision and Image Processing** The study of image acquisition, representation and pattern recognition, edge detection for computer vision. Topics to be covered include digital image formats, image storage and display, bilevel image processing, measurable properties of objects, grey-level image processing, image classification and object recognition.
COSC 726: Explainability and Fairness in Machine Learning (3 credits – Lecture) The machine learning models that power AI systems are often black boxes. This graduate level course aims to familiarize students with the recent advances in the emerging field of eXplainable Artificial Intelligence (XAI). It covers different classes of interpretable models and post hoc explanations (e.g., rule-based and prototype-based models, feature attributions, counterfactual explanations, mechanistic interpretability). This course also explores fundamental issues and concepts of fairness and bias in machine learning, and shows how different metrics can be used to address these problems.	None
COSC 586: Quantum Computing (3 credits) This course introduces the theory and practice of quantum computing and the equitable aspect of quantum computing. Topics covered include: the basics of quantum computing, math, quantum	None

theory, quantum architecture, and equitable quantum programming, Qiskit, intro to well-known quantum algorithms, QML, quantum machine learning, and quantum drug discovery. Prerequisite: None.	
COSC 614: Cryptography and Cryptology (3 credits – Lecture) This course explores modern cryptographic (code making) and cryptanalytic (code breaking) techniques in detail. Topics covered include cryptographic primitives such as symmetric encryption, public key encryption, digital signatures, and message authentication codes, cryptographic protocols, such as key exchange, remote user authentication, side-channel attacks, replay attacks, power analysis, and quantum cryptography. Prerequisites: COSC 502.	None
COSC 686: Quantum Algorithms and Architecture (3 credits)	None
COSC 724: Post Quantum Cryptography (3 credits)	None
COSC 511: Design and Analysis of Equitable Algorithms (3 credits – Lecture) This course presents advanced concepts of algorithm design and methods of algorithm analysis. Algorithm design focuses on solving complex computational and real-world problems while the Algorithm analysis focuses on determining algorithm complexities (both time and space), completeness and correctness proof, comparisons among available solutions, and efficient decision making. Prerequisites: None	**COSC 600: Advanced Data Structures and Algorithm Analysis** Data abstraction, linear data structures, file organization and access methods, memory management, advanced internal and external sort and search algorithms and the trade-offs involved in the use of different data organization.
COSC 558: Advanced Network Security (3 credits – Lecture) This course focuses on the protocols, skills and tools needed to support the development and delivery of advanced network and cloud services over the Internet. This graduate-level course is also focused on mastering technical details in a number	**COSC 734 Network Security** Principles and practice of network security. Topics include authentication services, email security, IP security, Web security, security systems and threats, wireless security, and security applications.

of areas of advanced networking through reading and hands-on activities of important research topics in the field. The topics covered in this course include 1) network and cloud basics; 2) protocols; 3) network and cloud security; 4) mobile computing; 5) software-defined networking; 6) network and cloud management; 7) datacenter management; 8) big data analytics and cloud. Prerequisites: COSC 551.	
COSC 612: Deep Learning in the Cloud (3 credits – Lecture) This course introduces Deep Learning (DL), learning complex and hierarchical feature representations from raw data. Topics include: fundamental principles of DL, underlying mathematics, and implementation details of deep learning with an emphasis on practical implementation of applications through in-depth programming assignments. Prerequisite(s) COSC 502 Offered AS NEEDED	**COSC 750: Neural Networks and Deep Learning** Discussion of neural network and deep learning, architectures, algorithms and applications, including feedforward neural networks, backpropagation, convolutional neural networks, recurrent neural networks, LSTM, deep belief networks, autoencoders, generative models, and Boltzmann machines
COSC 721: Equitable High Performance Computing (3 credits – Lecture) This course will focus on equitable computing and discuss advanced topics of parallel systems covering topics ranging from what an HPC cluster consists of to how to efficiently solve complex large-scale problems in the areas of computational fluid dynamics, image processing, machine learning and analytics on these systems. Prerequisites: COSC 502	**COSC 740 Parallel Computing** Parallel computing and its applications including parallel computer models, parallel matrix algorithms, optimization algorithms, complexity of parallel algorithms, parallel programming environment, application of parallel algorithms in sorting, searching, matrix operations, system of linear equations and optimization.
COSC 722: Equitable Machine Learning Applications (3 credits – Lecture) The course is to study ethical and equitable aspects of machine learning and their applications. It is a subfield of Artificial Intelligence and intersects with statistics, cognitive science, information theory, and probability theory, among others. The course will explain how to build systems that learn and adapt using examples from real-world applications. Prerequisite: COSC 502	**COSC 757: Data Mining** Designed to provide students with a broad background in data mining techniques and related topics. Real-world applications including Web mining will be emphasized. Current data mining tools will be used in student projects.