MORGAN STATE UNIVERSITY
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September 1, 2023

Acting 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 Computing.* This new degree was approved by the Board of Regents on August 1, 2023.

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 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 # JCMSU110 ( ) Check # JCMSU110
Payment Amount: 850
Date Submitted: 8/4/23

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 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: Hongtao Yu	
	Title: Provost and Senior Vice President for Academic Affairs	
	Phone: (443) 885-3500	
	Email: Hongtao.Yu@morgan.edu	
President/Chief Executive	Type Name: David Wilson	
	Signature: [signature]	Date: 09/01/2023
	Date of Approval/Endorsement by Governing Board:	08/01/2023

Revised 1/2021

Morgan State University

School of Computer, Mathematics, and Natural Sciences

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

A. Centrality to Institutional Mission Statement and Planning Priorities

Morgan State University (Morgan) proposes a new academic graduate degree program, Doctor of Philosophy in Advanced Computing (hereafter "Ph.D. in Advanced Computing" or "Program"). The Program is offered through the Department of Computer Science (CS) of the School of Computer, Mathematics, and Natural Sciences in collaboration with the School of Engineering and School of Business, Morgan State University.

A.1. Program Description

A.1.1 Motivation

We define Advanced Computing to be the ***intersection of Artificial Intelligence (AI), Cybersecurity, Big Data, Cloud Computing, Mobile Computing, Quantum Computing, High Performance Computing (HPC), Robotics, and other emerging areas within the broader sphere of computer science***. The Morgan Advanced Computing doctoral program will preserve the core of computer science (CS) while offering specialized training for underrepresented groups in the emerging areas of AI, cybersecurity, cloud computing, quantum computing, and data science. As an HBCU, the computer science department at Morgan State University is uniquely qualified to produce program graduates from underrepresented groups. Furthermore, the proposed Ph.D. program is a natural extension of the already established MS in Advanced Computing Program, which had enrolled 39 students in spring 2023 and currently has 135 students on record (continuation and new applicants). Not only will the program be attractive to prospective applicants outside of Morgan, but, equally importantly, it will offer graduates from our MS in Advanced Computing Program 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 computing field. Research has shown that it is a unique program in Maryland and the only Advanced Computing doctoral program in the nation.

The advancement of AI and Machine Learning (ML) has accelerated the adoption and integration of new innovations into many frontiers including automobile, finance, defense and industrial applications. Analyzing big data with advanced computing systems can reveal underlying relationships that humans can easily miss. Natural language processing (NLP) tools driven by AI such as ChatGPT have gained widespread attention. On the theoretical side, ML and Deep Learning (DL) algorithms are able to not only analyze data efficiently but also accumulate the knowledge gained from previous learning. Computational Data Science and Big Data have emerged as burgeoning new disciplines due to the rapid explosion of data information from every aspect of our life. Cybersecurity, equity, and ethics in computing are also having a huge impact on society. It is therefore imperative that our program encompass a group of emerging subject matter so that next generation practitioners can step into leading roles within these areas. Due to the tremendous growth of these specializations, there is an obvious need to develop courses and train

our students at the doctoral level. Advances in computational science will continue to drive technology and it is our mandate to ensure that equity is maintained within these venues of study.

Computer science and advanced computing specializations have been the driver of incredible job growth and innovation throughout our economy in the areas of AI, cybersecurity, cloud computing, robotics, Internet of Things (IoT), software engineering, and data science. Cybersecurity has been a top concern for government and private sector and the cyber workforce development has been one of the top priorities to fill the much-needed job vacancies. 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 on-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 an doctoral degree in advanced 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 computing in many domains has also led to the recent emergence of new degree programs at several institutions. The doctoral program in Advanced Computing program at Morgan would provide a specialized focus in an area of science and technology, helping develop skills and career prospects. 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 Computing is sixty (60) equivalent credit-hours beyond the bachelor's degree or thirty-six (36) equivalent credit-hours beyond the masters' degree, pass comprehensive, and submit an acceptably written dissertation. Candidates who hold high-level 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 (see Tables A and B) are comprised of: (a) Core Courses (each credit is equivalent to 1 credit-hour of graduate coursework) 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 high-level 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 a Ph.D. immediately 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 a Ph.D. immediately 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 the 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 master's 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.

Masters in Computer Science
Masters in Electrical Computer Engineering
Masters in Software Engineering, AI, Cybersecurity, Data Science
Masters in Information Science/Technology .

Table C: List of approved Master's Degree programs for direct admission to the Ph.D. in Advanced 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

This new program provides a platform for a growing population of students including those who are under-represented 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 prepared for specialized jobs with focus on an area of emerging technology, involving cutting edge aspects of Computer Science that are fundamentally important and practically relevant. The possibility of completing a doctoral degree in Advanced Computing remotely makes it possible for working professionals to enroll into this program that would otherwise not be possible to study in classrooms during the working hours.

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 quite successful and has been rapidly expanding. The enrollment increased **five times** (from 12 to 60) within three years. Consequently and unfortunately, our Computer Science department has been having difficulty hiring faculty who are themselves URMs. The department currently has four openings with over a hundred applicants. Unfortunately, few are URMs. The new program will educate and train advanced computer scientists, especially URM professionals, to fill in the gap in academia and industry.

The CS department is dedicated to fulfilling these missions by preparing students, especially URMstudents 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 the society.

A.2. Strategic Goals Support and Affirmation

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 Computing program supports 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 Ph.D. in Advanced Computing 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 (CEAMLS) and Cybersecurity Assurance & 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.
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> **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 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.
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> **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 State University 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 Computer Science has established a Trustworthy AI Lab with a number of AI/ML related projects and publications. Bezos Fund, Meta (Facebook) and Google have awarded projects on AI/ML to Morgan computer science 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

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. Combining 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 AI/ML, Cybersecurity, Data Mining, Data Analytics, and Cloud Computing, 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. Whereas, 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.

Whereas, 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 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 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

The demand for employees with Advanced Computing and computing expertise with advanced degrees is high and it has grown steadily over time. According to data from the Bureau of Labor Statistics (BLS) employment in computer 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 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 computer and information research scientists, 20% for 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 Computer Science workers is expected to grow by another 12 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, and there are close to 10,000 openings throughout the nation. Yet, state colleges and universities graduated fewer than 3,000 Computer Science majors yearly on average, and only 20% were female and the number of graduates with an Ph.D. degree in Advanced 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 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 $124,520 per year (2021) according to the U.S. Bureau of Labor Statistics.

Machine learning engineers, cloud computing professionals, cybersecurity, data scientists, and big data engineers rank among the top emerging jobs -- with companies in a wide range of industries seeking those skills. Data science and machine learning are generating more jobs than candidates right now, making these two areas the fastest growing tech employment areas today. Data scientist roles have grown over 650% since 2018, but currently 35,000 people in the US have data science skills, while hundreds of companies are hiring for those roles - even those you may not expect in sectors like retail and finance - supply of candidates for these roles cannot keep up with demand. 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. There are 6.5 times more Data Scientists than five years ago, and 5.5 times more Big Data Developers. Based on insights from Glassdoor's 50 Best Jobs In America For 2021, Data Scientist has been named one of the best job in America for three years in a row, with a median base salary of $120,000 with 4,524 job openings. Six analytics and data science jobs are included in Glassdoor's 50 best jobs In America for 2021. Across all six analytics and data science jobs there are 16,702 openings as of today according to Glassdoor. Whereas, software engineering is a common starting point for professionals who are in the top five fastest growing jobs today. The career path to Machine Learning Engineer and Big Data Developer 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 cloud computing expertise continues to increase exponentially and will accelerate in 2023 and beyond. According to Forbes, there are currently 50,248 cloud-computing positions available in the U.S. with the median salary of $146,350. According to the Association for Computing Machinery (ACM), cloud computing is among the top 10 jobs for the next decade. It continues to be an area of job growth, leading to new titles such as digital logistics manager.

MSU should capitalize on the growing interest and professional opportunities in computer science and expand its offerings to accommodate the growing demand of computing skills in those above fields and 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 Ph.D. in Computer Science is offered in several institutions in Maryland, the proposed advanced computing program with the emerging areas in computer science courses 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, and University of Maryland College Park within the State of Maryland. Towson University offers Ph.D. in Information Science.

Johns Hopkins University offers a Ph.D. in computer science with a range of tracks including data science, cloud computing, cybersecurity, and software engineering. Johns Hopkins University 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 Ph.D. in computer science program covers algorithm and theory, AI, databases, machine learning, and many other emerging areas. It is designed for full-time students.

The Morgan Ph.D. in Advanced Computing program is a **unique** program in the State of Maryland that has the option for students to study from remote, in addition to study onsite (students may choose modality course-to-course). This will attract both working professionals and college graduates. A residence requirement 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 computer science in AI, cybersecurity, data science, cloud computing, and quantum

computing/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 degrees.

The existing computer science or related doctoral programs in Maryland have very limited overlap with our proposed program. University of Maryland Baltimore County offers a general Ph.D. in computer science with no focus areas; Bowie State University offers an 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 in quantum computing, AI/ML, cybersecurity, and HPC. In fact, the concepts of cybersecurity, quantum computing, and machine learning which are the key concepts in our program are absent in their programs.

Morgan State University is collaborating with Google in AI/ML with grants and learning materials. MSU 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 on machine learning, cybersecurity, IoT, and data analytics. IBM has awarded 6 Master's awards to the MSU computer science department in quantum computing. The agreement with NSA 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 with other existing programs.

In summary, the proposed PhD in Advanced Computing program focuses on cybersecurity, cloud computing, quantum computing, machine learning, and data science with the online and onsite delivery methods is a unique program. It does not duplicate any programs in the State. Instead, it complements the existing programs with a strong workforce development focus and advanced computing foundation.

2. Provide justification for the proposed program.

Due to growing market demand among high tech companies, PhD in Advanced Computing is not widely offered in the U.S. This high-demand also presents an opportunity for MSU to provide underrepresented minority students to major in PhD in Advanced Computing.

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

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

With the growing enrollment of computer science undergraduate majors at MSU from 204 to 446 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. In fact, the concept of cyber security, cloud computing, and machine learning which are the key concepts in our program are absent in their program. 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 Ph.D. in Advanced Computing provides a platform for fulfilling the pipeline of underrepresented computer scientists to 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 research.

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 fundamental and innovative fields in computer science such as machine learning with a focus on deep learning, artificial intelligence and intelligence computing, cloud computing, quantum computing, data science, information technology and software engineering can further promote such activities.

F. Relevance to the Identity of Historically Black Institutions (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[1]. 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] www.morgan.edu/Documents/ACADEMICS/Academic.../ucat_AcademicAffairs.pdf

PhD in Advanced Computing students are expected to proactively pave a foundation of knowledge and skills in computer science out of course work, 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.

Learning Outcomes

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

- Understand and explore in-depth knowledge in Computer Science, its impact, and connect Computer Science from the perspective of different disciplines and application domains;
- Demonstrate high-level understanding of principles, contributors, developments and contemporary applications of Computer Science in specific area of interest;
- Demonstrate competency, commitment, knowledge and skills in applying principles to practical situations in any area of interest;
- Solve practical and challenging Computer Science problems;
- Use and deploy Computer Science principles and tools;
- Visualize complex and heterogeneous data in user-friendly ways with perceivable inferences and interpretations;
- 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;
- Demonstrate knowledge of problem-solving techniques in the basic concepts and principles of both theoretical and applied sciences;
- Enhance knowledge and demonstrate the impact through both project and dissertation; For professionals, to gain necessary foundations and skills through appropriate course work;
- Use the knowledge and skills acquired for advancement in the workplace in different application domains.

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 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**) from the four focus areas (Algorithms and Computation Theory, Network and Security, Computer Systems, and Artificial Intelligence & Machine Learning). 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 be 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 combination of Independent Study, dissertation research (4), 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 and at least one course from each of the four knowledge areas:

   <u>Algorithms and Computation Theory</u>

   - COSC 511: Design and Analysis of Algorithms (3 credits)
   - COSC 512: Software Engineering (3 credits)
   - COSC 611: Big Data Analytics (3 credits)
   - COSC 711: Quantum Algorithms (3 credits)

   <u>Network and Security</u>

   - COSC 551: Cybersecurity (3 credits)
   - COSC 504: Secure Cloud Computing (3 credits)
   - COSC 558: Network Security (3 credits)
   - COSC 721: High Performance Computing (3 credits)

   <u>Computer Systems</u>

   - COSC 513: Cloud Computing Applications (3 credits)

- COSC 614: Cryptology and Cryptography (3 credits)
- COSC 586: Quantum Computing (3 credits)
- COSC 723: Advanced Computer Architecture (3 credits)

AI and ML

- COSC 502: Data Science and Artificial Intelligence (3 credits)
- COSC 572: Advanced Machine Learning (3 credits)
- COSC 672: Reinforcement Learning (3 credits)
- COSC 612: Deep Learning in the Cloud (3 credits)

Prerequisite courses: data structure, discrete math, computer organization, computer architecture, intro 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 638: Computational Usability & Ergonomics	3
COSC 680: Image Understanding & Computer Vision	3
COSC 686: Quantum Algorithm and Architecture	3
COSC 722: Machine Learning Applications	3
COSC 724: Post Quantum Cryptography	3
EEGR 750: Trustworthy Machine Learning	3
EEGR 755: Advanced Software Assurance	3
INSS 854: Information Systems Security	3

Note: courses listed at section a as core courses may be used to fulfill the elective course requirements; however, courses listed in section a will fulfill the core course requirement first.

c**. 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 credits)	
COSC 791: Special Topics in Computer Science	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. from the Master's Degree (36 Credits)

Core and Elective Courses (12 credits)

12 credit hours from the Core Courses. Select four (4) courses from below. At least 4 courses deriving from at least 4 different areas listed below:

Algorithms and Computation Theory

- COSC 511: Design and Analysis of Algorithms (3 credits)
- COSC 512: Software Engineering (3 credits)
- COSC 611: Big Data Analytics (3 credits)
- COSC 711: Quantum Algorithms (3 credits)

Network and Security

- COSC 551: Cybersecurity (3 credits)
- COSC 504: Secure Cloud Computing (3 credits)
- COSC 558: Network Security (3 credits)
- COSC 721: High Performance Computing (3 credits)

Computer Systems

- COSC 513: Cloud Computing Applications (3 credits)
- COSC 614: Cryptology and Cryptography (3 credits)
- COSC 586: Quantum Computing (3 credits)
- COSC 723: Advanced Computer Architecture (3 credits)

AI and ML

- COSC 502 Data Science and Artificial Intelligence (3 credits)
- COSC 572: Advanced Machine Learning (3 credits)
- COSC 672: Reinforcement Learning (3 credits)
- COSC 612: Deep Learning in the Cloud (3 credits)

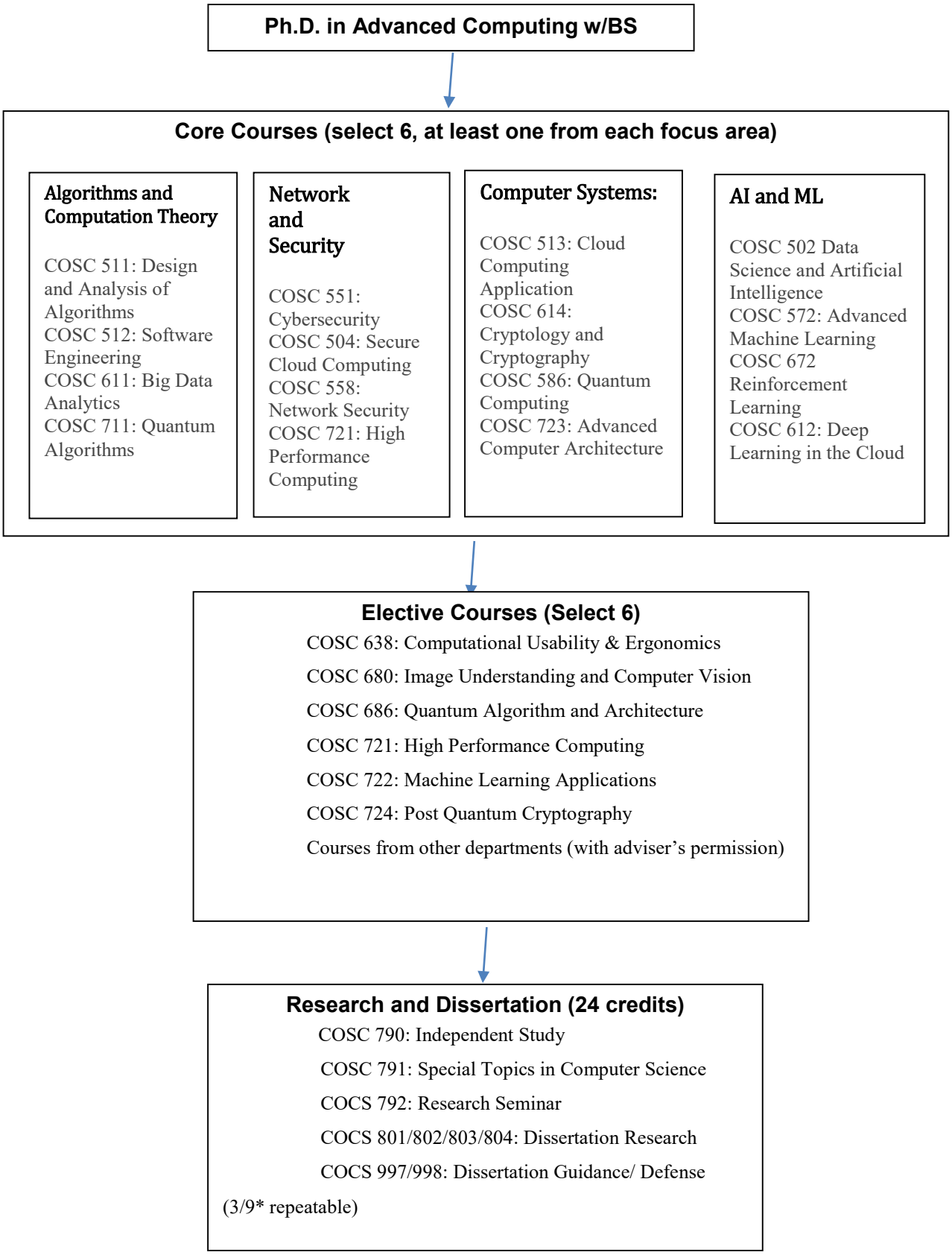
Other Courses

- COSC 638: Computational Usability & Ergonomics 3
- COSC 680: Image Understanding & Computer Vision 3
- COSC 686: Quantum Algorithm and Architecture 3
- COSC 721: High Performance Computing 3
- COSC 722: Machine Learning Applications 3
- COSC 724: Post Quantum Cryptography 3
- EEGR 750: Trustworthy Machine Learning 3
- EEGR 755: Advanced Software Assurance 3
- INSS 854: Information Systems Security 3

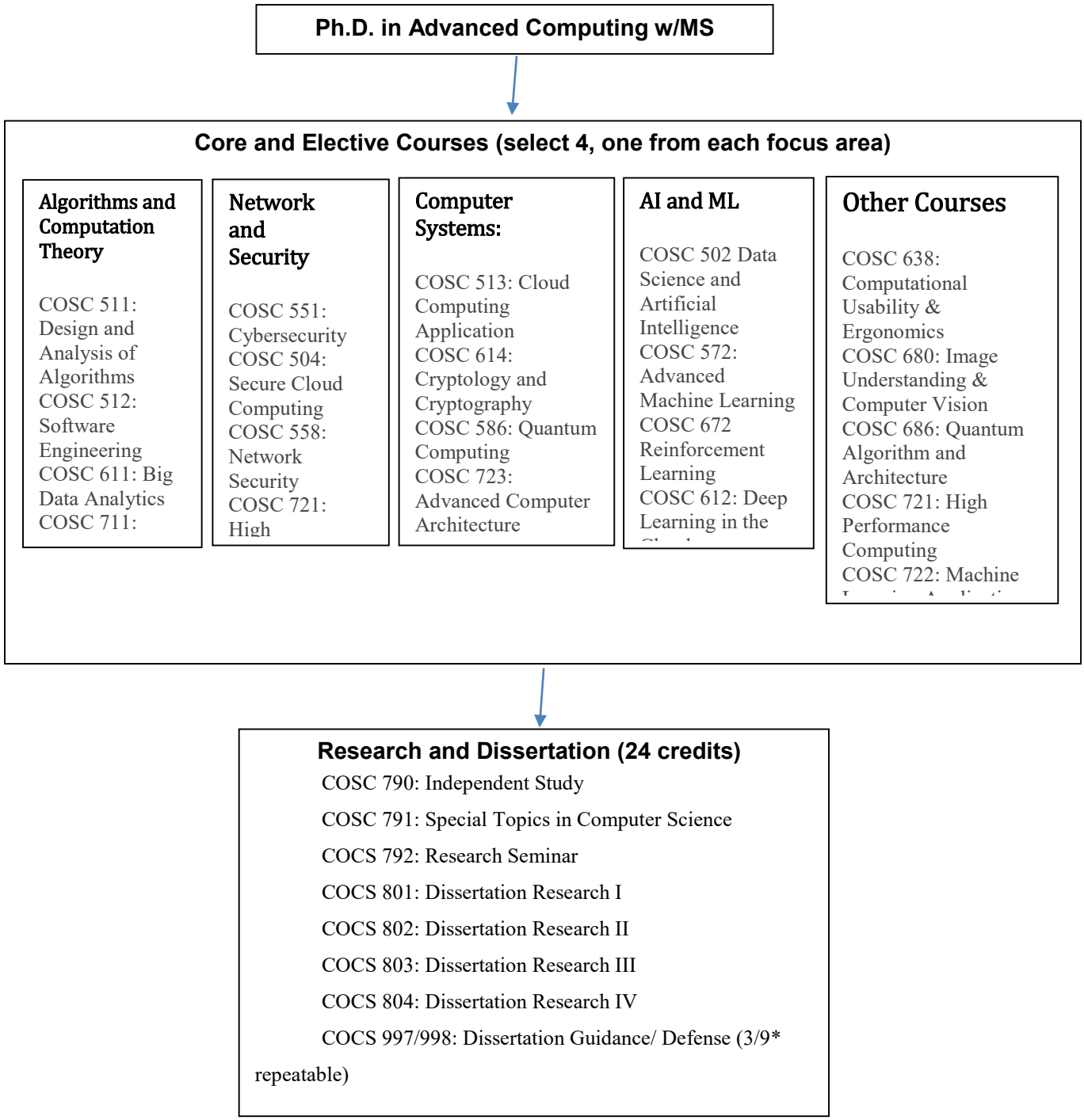
Dissertation Research Courses (24 credits)
The remaining **24 credits** will be for dissertation research where courses will be selected from following:

- COSC 790: Independent Study 3
- COSC 791: Special Topics in Computer Science 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 Computing Organogram (from a Bachelor's degree):



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



Course Description

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

This course covers a wide range of statistical models 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.

COSC 504: Secure Cloud Computing [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 502

The course examines the most important cloud services and APIs used in the Amazon and Microsoft Cloud, including the techniques for building, deploying, and maintaining machine images and applications. Students will learn how to use Cloud as the infrastructure for existing and new services. Students will use open-source implementations of highly available clustering computational environments, as well as RESTFul Web services, to build powerful and efficient applications. Students also learn how to deal with cloud management, such as load balancing, caching, distributed transactions, and identity and authorization management and security.

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 [existing course]
Three hours lecture; 3 credits.
Prerequisites: None

This course introduces these components broadly covering the fundamentals of modern 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 513: Cloud Computing Applications [existing course]
Three hours lecture; 3 credits.

Prerequisites: None

This course offers the fundamentals and principles of cloud computing and its different aspects. Starting with the essential concepts and technologies of cloud computing, this course will introduce the relevance of the platform to real-world business and applications. Along with covering the constituent components, topics would include cloud models, service requirements, infrastructure, security, costs, and benefits. The course will also discuss different cloud platforms, models, and services.

COSC 551: Cybersecurity [existing course]
Three hours lecture; 3 credits.
Prerequisites: None

This course focuses on the protection of information systems against unauthorized access to or modification of information, whether in storage, processing or transit, and against the denial of service to authorized users, including those measures necessary to detect, document, and counter such threats. This course creates sensitivity to the threats and vulnerabilities of information systems, recognition of the need and means to protect data and information, and builds a working knowledge of principles and practices in information security. The course covers cryptography basics, intrusion detection and prevention, digital forensics, and uses cybersecurity tools such as Wireshark, FTK Imager, and Kali Linux to simulate attacks and preventions in a live setting.

COSC 558: 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 572: Advanced Machine Learning [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 220

This course studies Neural Networks (NN) and applies it to mimic human brains. While NN is yet to attain the same level as humans, recent development has shown some promises and excitement. Topics in this class include Perceptron Learning, Feedforward Neural Networks, Regularizations, Optimization, convolutional neural network, Word Embedding and Language Models, Sequence Modeling: Recurrent and Recursive Nets, Linear Factor and Auto Encoders, and Deep Generative Models.

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

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

COSC 611: Data Analytics [existing course]
Three hours lecture; 3 credits.
Prerequisites: COSC 502

The focus of this course is analyzing Big Data. It serves as an introductory course for graduate students who want to handle challenges with Big Data storage, curation, processing, analysis, visualization, and application at workplaces, research environments, and industry. Get insight on appropriate tools, algorithms, analytics, and platforms to use on real world problems. This interactive course will teach students how to use data science and machine learning techniques to quickly analyze network and security data and ultimately uncover valuable insights from this data. The course will cover the entire data science process from data preparation, feature engineering and selection, exploratory data analysis, log analysis, data visualization, machine learning, model evaluation and optimization and finally, implementing at scale—all with a focus on cybersecurity as the core.

COSC 612: Deep Learning in the Cloud [existing course]
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 638: Computational Usability & Ergonomics [existing course]
Three hours lecture; 3 credits.
Prerequisites: none

The cross-section of Usability and Ergonomics examines the impacts of employed computational technologies on end-users. This course will explore both usability and ergonomics practices pertaining to developed computational technologies from the aspect of educational, humanistic,

and societal settings. In this course, students will learn both the importance of user impact and satisfaction and the environmental/social effects that must be considered when developing computational technologies with end-users in mind.

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

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 and, additionally, will survey recent developments in deep reinforcement learning research. Lecture materials will be supplemented with coding and research projects designed to explore reinforcement learning applications.

COSC 680: Image Understanding and Computer Vision [existing course]
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 focuses on 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 libraries.

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

The Study of quantum algorithms in speeding up the execution, optimization, 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: High Performance Computing [newly proposed course]
Three hours lecture; 3 credits.
Prerequisites: COSC 502

This course will 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: Machine Learning Applications [newly proposed course]
Three hours lecture; 3 credits.
Prerequisites: COSC 672

The course is to study how to build computer systems that learn from experience. 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 will 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 723: Advanced Computer Architecture [newly proposed course]
Three hours lecture; 3 credits.
Prerequisites: COSC 558

Design and evaluation of modern uniprocessor computing systems. Evaluation methodology/metrics and caveats, instruction set design, advanced pipelining, instruction level parallelism, prediction-based techniques, RISC-V, alternative architectures (VLIW, Vector and SIMD), memory hierarchy design, I/O, and recent trends in architecture. The course will also cover new architecture such as quantum computing architecture.

COSC 724: Post Quantum Cryptography [newly proposed 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 790: Independent Study [newly proposed 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 [newly proposed 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, crosslist 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.

COSC 801: Dissertation Research I [newly proposed 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 [newly proposed course]
Three Hours: 3 Credits
Prerequisite: None
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 [newly proposed course]
Three Hours: 3 Credits
Prerequisite: None
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 [newly proposed course]
Three Hours: 3 Credits
Prerequisite: None
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 [newly proposed 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 [newly proposed 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 [newly proposed 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).

H. Adequacy of Articulation

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

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. In addition to current faculty at MSU, four (4) new tenure track assistant/associate professor positions have been approved. Those new faculty are being recruited to staff the proposed new program. These positions will be filled in the fall of 2023 and beyond.

See Appendix A for Table of Ph.D. in Advanced 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 at this program will have terminal degrees.

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 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.

Computer Science Faculty	
Dr. Shuangbao Wang	Professor and chair, Department of Computer Science
full-time faculty	PhD computer science, COSC 614, 711
Dr. Mohamed Eltoweissy	Professor, Department of Computer Science
full-time faculty	PhD computer science, COSC 721
Dr. Md Rahman	Associate Professor, Computer Science
full-time faculty	PhD computer science, COSC 502, 680
Dr. Vojislav Stojkovic	Associate Professor, Computer Science
full-time faculty	PhD computer science, COSC 611, 612
Dr. Eric Sakk	Associate Professor, Computer Science
full-time faculty	PhD ece, COSC 686, 723
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
Dr. Guobin Xu	Associate Professor, Computer Science
full-time faculty	PhD Information Science, COC 558, 724
Dr. Monireh Dabaghchian	Assistant Professor, Computer Science
full-time faculty	PhD ece, COSC 551, 558
Dr. Naja Mack	Assistant Professor, Computer Science
full-time faculty	PhD computer science, COSC 722
To be hired (position open)	Assistant/Associate Professor, Computer Science
full-time faculty	TBD

To be hired (position open)	Assistant/Associate Professor, Computer Science
full-time faculty	TBD
To be hired (position open)	Assistant/Associate Professor, Computer Science
full-time faculty	TBD
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
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
Ph.D. in Advanced Computing Program: Faculty positions (Approved positions to be hired)	
Assistant/Associate/full Professor (position open)	Computer Science (AI, Cyber, Quantum, Cloud and other related areas)
Assistant/Associate/full Professor (position open)	Computer Science (AI, Cyber, Quantum, Cloud and other related areas)

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.

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

J.1. MSU Library[2]

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.

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

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.

The four to six floors of the McMechen building are being renovated and the Computer Science department will occupy the space. 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 Data Science and Machine Learning Laboratory is in Calloway Hall, Room 304. It has 20 PCs connected in a network. Each computer has specific computing platforms installed, and Windows 10 and Linux Operating Systems are available. The laboratory has a variety of software for Computer, Network, and Data Science, Bioinformatics and Computational Biology, Concurrent, Parallel, and Distributed Computing, Modeling and Simulation, Visualization. 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 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 newly established quantum cryptography lab has the world class quantum key distribution devices and single photon quantum education system (cost over $250k). The ID Quantiqe QKD device sits in the newly established quantum cryptography lab in the computer science department.

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

1. Resource Allocation

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 $536.50/credit for in-state students (2020-2022 tuition and fee schedule).

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

4. Other Sources: No other sources.

2. Expenditures

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)

The courses, the program' 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)

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, MSU, 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

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 State University 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 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, MSU has the following active onsite/online programs:

- MS in Advanced Computing, 42 students, 8 graduates. 2020-2022
- Community College Leadership Program (Ed.D.), 15 graduates in 2020-2022
- Master of Business Administration (MBA), 19 graduates in 2020-2022
- Master of Social Work (MSW), 56 graduates in 2020-2022
- Master of Science 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]