CAPITOL
Technology University

Bradford L. Sims, PhD
President

January 6, 2020

Dr. James D. Fielder, Jr.
Secretary of Maryland Higher Education
Maryland Higher Education Commission
6 N. Liberty Street
Baltimore, MD 21201

Dear Dr. Fielder,

Capitol Technology University is requesting approval to offer a **Doctor of Philosophy (Ph.D.) in Quantum Computing**. The degree curriculum will be taught using the existing faculty at our university and will be supported by the development of new courses. The mission of Capitol Technology University is to provide a practical education in engineering, computer science, information technology, and business that prepares individuals for professional careers and affords the opportunity to thrive in a dynamic world. A central focus of the university's mission is to advance practical working knowledge in areas of interest to students and prospective employers within the context of Capitol Tech's degree programs. The university believes that a **Ph.D. in Quantum Computing** is consistent with this mission.

The requirement for experts in quantum computing at the highest level is experiencing significant growth. This program is in response to that need. The **Ph.D. in Quantum Computing** degree is primarily for experienced quantum computing personnel who desire to advance in their careers by earning a doctoral degree.

To respond to needs of the quantum computing field, we respectfully submit for approval a Doctor of Philosophy (Ph.D.) in Quantum Computing. The required proposal is attached as well as the letter from me, as university president, confirming the adequacy of the university's library to serve the needs of the students in this degree.

Respectfully,

Bradford L. Sims, PhD

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President

January 6, 2020

Dr. James D. Fielder, Jr.
Secretary of Maryland Higher Education
Maryland Higher Education Commission
6 N. Liberty Street
Baltimore, MD 21201

Dear Dr. Fielder,

This letter is in response to the need for confirmation of the adequacy of the library of Capitol Technology University to support the proposed **Doctor of Philosophy (Ph.D.) in Quantum Computing**. As president of the university, I confirm that the library resources, including support staff, are more than adequate to support the **Ph.D. in Quantum Computing**. In addition, the university is dedicated to, and has budgeted for, continuous improvement of its library resources.

Respectfully,

Bradford L. Sims, PhD

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

Institution Submitting Proposal	Capitol Technology 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

Department Proposing Program	Department of Doctoral Programs	
Degree Level and Degree Type	Doctor of Philosophy (Ph.D.)	
Title of Proposed Program	Ph.D. in Quantum Computing	
Total Number of Credits	60	
Suggested Codes	HEGIS: 0701	CIP: 11.0701
Program Modality	( ) On-campus (●) Distance Education (*fully online*) ( ) Both	
Program Resources	(●) Using Existing Resources ( ) Requiring New Resources	
Projected Implementation Date	( ) Fall ( ) Spring (●) Summer	Year: 2020
Provide Link to Most Recent Academic Catalog	URL: https://www.captechu.edu/current-students/academic-resources	
Preferred Contact for this Proposal	Name: Professor Soren Ashmall	
	Title: Director, Assessment and Accreditation	
	Phone: (571) 332-4344	
	Email: spashmall@captechu.edu	
President/Chief Executive	Type Name: Dr. Bradford Sims	
	Signature: [signature]	Date: 1-6-20
Approval/Endorsement by Governing Board	Type Name: Dr. Bradford Sims	
	Signature: [signature]	Date: 01-06-2020

Revised 5/15/18

Proposed Doctor of Philosophy in Quantum Computing
Department of Doctoral Programs
Capitol Technology University
Laurel, Maryland

A. Centrality to Institutional Mission 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.**

Doctor of Philosophy in Quantum Computing Program Description:

The **Doctor of Philosophy (Ph.D.) in Quantum Computing** provides students with the opportunity to conduct extensive and sustained original research at the highest level in the field of Quantum Computing. Quantum Computing harnesses and exploits the laws of quantum mechanics to process information. Using the phenomena of superposition and entanglement, a quantum computer can process a vast number of calculations simultaneously. Difficult tasks that were once thought impossible for classical computers can be achieved quickly and efficiently using a Quantum Computing. The **Ph.D. in Quantum Computing** is a unique doctoral program designed to meet the demands of the highest skilled professionals to become the leaders who will be involved in the advancement, expansion, and support of the Quantum Computing field. Quantum Computing is one of the technological arenas that is rapidly expanding with significant advancements occurring regularly. As such, there is a need for innovative researchers and practitioners who desire to elevate their skills to the highest level and contribute to the body of knowledge in Quantum Computing.

The proposed **Ph.D. in Quantum Computing** degree is designed for current professionals in the field. The degree provides a path for Quantum Computing personnel to explore new ground and create technological breakthroughs. The University is in a unique position to provide those students with an avenue to pursue a deep proficiency in this area using an interdisciplinary methodology, cutting-edge courses, and dynamic faculty skill sets. Graduates will contribute significantly to the Quantum Computing field through the creation of new knowledge and ideas. The **Ph.D. in Quantum Computing** program is designed as a doctorate by research where students will quickly become able to engage in research and publishing.

Relationship to Institutional Approved Mission:

The **Ph.D. in Quantum Computing** is consistent with the University mission to educate individuals for professional opportunities in engineering, computer science, information technology, and business. The University provides relevant learning experiences that lead to success in the evolving global community. The **Ph.D. in Quantum Computing** supports that philosophy in a key growing STEM area. The **Ph.D. in Quantum Computing** degree also compliments the University's existing degree programs.

The **Ph.D. in Quantum Computing** degree will be offered online using the Canvas Learning Management System and Zoom. The result is the convenience required by the 21st Century learner and provides the interaction with faculty and fellow students that is critical to the high-

level learning experience. The curriculum provides the doctoral student the necessary learning tools that the University believes critical to success as a leader in the Quantum Computing field. The degree is also consistent with the interdisciplinary nature of the University.

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

Capitol Technology University operates on four strategic goals:

1. **Expand Educational Offerings, Increase Program Completion:** *Capitol Technology University is an institution that offers career-relevant curricula with quality learning outcomes. The strategy includes continuing to expand educational offerings, increasing program completion, and raising learner qualifications and outcomes.*

2. **Increase Enrollment and Institutional Awareness:** *Capitol will accelerate its goal pursuit to become more globally renowned and locally active through student, faculty and staff activities. Enrollment will grow to 650 undergraduates, 350 masters' students and 250 doctoral candidates.*

3. **Improve the Utilization of University Resources and Institutional Effectiveness While Expanding Revenue**: *Capitol will likely continue to be 80% financially dependent on student tuition and fees. We plan to enhance our resources by expanding the range and amount of funding from other streams and aligning costs with strategic initiatives.*

4. **Increase the Number and Scope of Partnerships**: *Capitol's service to our constituents and sources of financial viability both depend upon participation with continuing and new partner corporations, agencies, and schools.*

The proposed **Ph.D. in Quantum Computing** program supports all the University's four strategic goals. The proposed degree builds upon the existing areas of graduate study, including the Master of Business Administration (M.B.A.), Master of Science (M.S.) in Aviation, Master of Science (M.S.) in Aviation Cybersecurity, Master of Science (M.S.) in Computer Science, Master of Science (M.S.) in Construction Cybersecurity, Master of Science (M.S.) in Construction Safety, Master of Science (M.S.) in Critical Infrastructure, Master of Science (M.S.) in Cyber Analytics, Master of Science (M.S.) in Cybersecurity, Master of Science (M.S.) in Information Systems Management, Master of Science (M.S.) in Engineering Technology, Master of Science (M.S.) in Internet Engineering, Technical Master of Business Administration (T.M.B.A.) in Business Analytics and Data Science, and Technical Master of Business Administration (T.M.B.A.) in Cybersecurity, Master of Science (M.S.) in Unmanned and Autonomous Systems Policy and Risk Management, Doctor of Science (D.Sc.) in Cybersecurity, Doctor of Philosophy (Ph.D.) in Artificial Intelligence, Doctor of Philosophy (Ph.D.) in Aviation, Doctor of Philosophy (Ph.D.) in Business Analytics and Decision Sciences, Doctor of Philosophy (Ph.D.) in Construction Science, Doctor of Philosophy (Ph.D.) in Critical Infrastructure, Doctor of Philosophy (Ph.D.) in Manufacturing, Doctor of Philosophy (Ph.D.) in Occupational Health and Safety, Doctor of Philosophy (Ph.D.) in Product Management, Doctor of Philosophy (Ph.D.) in Technology, Doctor of Philosophy (Ph.D.) in Technology/Master of Science (M.S.) Research Methods Combination Program, Doctor of Philosophy (Ph.D.) in Unmanned Systems Applications. The University's graduate degree programs are structured to prepare students to provide leadership and technical expertise to meet the needs of a modern technology and information-dependent organization. The University's programs have been preparing professionals for rapid advances in information and

technology, intense global competition, and increasingly complex technological environments for decades. The **Ph.D. in Quantum Computing** will allow students to contribute to the body of knowledge in Quantum Computing.

The proposed **Ph.D. in Quantum Computing** is fully supported by the University's Vision 2025 and Strategic Plan 2017-2025. Funding to support the **Ph.D. in Quantum Computing** is already available within the existing budget.

The University has active partnerships in the private and public arenas (e.g., Parson Corporation, Leidos, Patton Electronics, Lockheed Martin, Northrup Grumman, Cyber Security Forum Initiative, IRS, and NCS). The **Ph.D. in Quantum Computing** degree will provide new opportunities for partnerships. The increase in partnerships and placement of our graduates in our partner institutions will serve to expand the University's enrollment and reputation. While additional enrollment will increase financial resources, additional partnerships and grants in the Quantum Computing field will help diversify and increase financial resources.

3. **Provide a brief narrative of how the proposed program will be adequately funded for at least the first five years of program implementation. (Additional related information is required in section L.)**

   Capitol Technology University will support the proposed program through the same process and level of support as the University's existing programs. The University has also budgeted funds to support program and course development, online support, office materials, travel, professional development, and initial marketing. There is no substantial impact to the institution due to the advanced budgeting of these funds. If approved, the program is expected to be self-sustaining going forward.

4. **Provide a description of the institution's a commitment to:**

   a. **Ongoing administrative, financial, and technical support of the proposed program**

      The proposed degree is an integral part of the University's Strategic Plan for FY 2017-2025 and forward. Funding for the administrative, financial, and technical support of the new degree has been included in the institutional and departmental budgets for FY 2019-2020 as well as the forecasted budgets going forward.

   b. **Continuation of the program for a period of time sufficient to allow enrolled students to complete the program.**

      Capitol Technology University is fully committed to continuing the proposed **Ph.D. in Quantum Computing** degree program for a sufficient period to allow enrolled students to complete the program.

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 advancement and evolution of knowledge.

Innovative new leaders are needed at the highest levels of Quantum Computing to create the next generation of quantum computing systems. More and more companies as well as universities, research institutes, and governments are becoming involved in quantum computing. There are current initiatives for quantum computing in many fields, including finance, commerce, business, manufacturing, and government. Those efforts are key indicators that quantum computing is moving from the arena of pure research and into practical applications. As a result, effective leadership in the field of Quantum Computing is critical.

The federal government is moving forward in the Quantum Computing arena. In late 2018, the White House issued a "National Strategic Overview" position paper on "Quantum Information Science." It was the first of many steps that will be taken at the national level.

The State of Maryland has a long history of fostering and encouraging new ventures as well as blazing new trails with groundbreaking research. If approved, this new degree will build on that legacy with a groundbreaking new doctoral program in a field that is rapidly developing with new technology. The University's **Ph.D. in Quantum Computing** program will help produce the next generation of top leaders with the technological expertise needed now and in the future by the Quantum Computing industry. Currently, the State of Maryland has no doctoral program in Quantum Computing. This degree program would help fill the gap.

b. Societal needs, including expanding educational opportunities and choices for minorities and educationally disadvantaged students at institutions of higher education.

Capitol Technology University is a diverse multiethnic and multiracial institution with a long history of serving minority populations. The University has a 51% minority student population with 7% undisclosed. The Black/African American population is 34%. The university has military/veteran population of 22%. The University also has a 22% female population – a significant percentage given its status as a technology institution. If approved, the proposed **Ph.D. in Quantum Computing** will expand the field of opportunities for minorities and disadvantaged students.

c. The need to strengthen and expand the capacity of historically black institutions to provide high quality and unique educational programs.

While Capitol Technology University is not a historically black institution, the university is a diverse multiethnic and multiracial institution with a long history of serving minority populations. The University has a 51% minority student population with 7% undisclosed. The Black/African American population is 34%. The University has military/veteran population of 22%. The university also has a 22% female population – a significant percentage given its status as a technology institution. If approved, the proposed **Ph.D. in Quantum Computing** will expand the field of opportunities for minorities and disadvantaged students.

A report from the Business-Higher Education Forum notes that African Americans and Hispanics represent just 6 and 7% respectively of STEM employment, even though they represent more than twice that much of the U.S. population. Given the substantial minority

population of Capitol Technology University, it is reasonable to assert that the **Ph.D. in Quantum Computing** program will add to this base of minority participation in the Quantum Computing profession.

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

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

The 2017-2021 Maryland State Plan for Postsecondary Education articulates three goals for postsecondary education:

1. Access
2. Success
3. Innovation

Goal 1: Access

"Ensure equitable access to affordable and quality postsecondary education for all Maryland residents."

Capitol Technology University is committed to ensuring equitable access to affordable postsecondary education for all Maryland residents. The University meets its commitment in this arena through its diverse campus environment, admissions policies, and academic rigor.

The Capitol Technology University community is committed to creating and maintaining a mutually respectful environment that recognizes and celebrates diversity among all students, faculty, and staff. The University values human differences as an asset and works to sustain a culture that reflects the interests, contributions, and perspectives of members of diverse groups. The University delivers educational programming to meet the needs of diverse audiences. We also seek to instill those values, understanding, and skills to encourage leadership and service in a global multicultural society.

The University's commitment to diversity is reflected in its student body. Capitol Technology University has a 51% minority student population with 7% undisclosed. The Black/African American population is 34%. The University has a military/veteran population of 22%. The University also has a 17% female population – a significant percentage given its status as a technology university.

Achievement gaps: The University provides leveling courses in support of individuals attempting a career change to a field of study not necessarily consistent with their current skills. There are situations where additional graduate and/or undergraduate courses best serve student needs in subject areas. The University makes those courses available.

The University engages in diversity training for its institutional population, including students. Diversity and inclusiveness are built into the curriculum allowing graduates to operate effectively in a global environment. The University supports multiple diversity enhancing actions, including team projects and grants across degrees. This has proven

effective at supporting multiple aspects of diversity.

Capitol Technology University does not discriminate on the basis of race, color, national origin, sex, age, sexual orientation, or handicap in admission, employment, programs, or activities.

Through its academic programs, Capitol Technology University seeks to prepare all of its graduates to demonstrate four primary characteristics:

- **Employability:** The ability to enter and advance in technical and managerial careers, appropriate to their level and area of study, immediately upon graduation.
- **Communications:** Mastery of traditional and technological techniques of communicating ideas effectively and persuasively.
- **Preparation of the Mind:** The broad intellectual grounding in technical and general subjects required to embrace future technical and managerial opportunities with success.
- **Professionalism:** Commitment to life-long learning, ethical practice and participation in professions and communities.

The proposed **Ph.D. in Quantum Computing** program and University financial aid will be available to all Maryland residents who qualify academically for admission. The University has successfully managed supporting Financial Aid for doctorate students since its first doctoral courses started.

The **Ph.D. in Quantum Computing** program, with its academic rigor, will produce highly qualified Quantum Computing professionals for this critical field of study and employment. The University has a proven record of rigorous high-quality education. The University is fully accredited by five accrediting organizations. The University receives its regional accreditation from the Middle States Commission on Higher Education (MSCHE). The University also has specialized accreditation from the International Accreditation Council of Business Education (IACBE), Accreditation Board for Engineering and Technology (ABET), and National Security Agency (NSA)/Department of Homeland Security (DHS). The **Ph.D. in Quantum Computing** program is consistent with the MSCHE criteria for regional accreditation of the delivery of high-quality higher education.

Goal 2: Success

"Promote and implement practices and policies that will ensure student success."

The courses for the **Ph.D. in Quantum Computing** will be offered online using the Canvas Learning Management System and Zoom. The University provides a tuition structure that is competitive with its competitors. The University tuition structure does not differentiate between in-state and out-of-state students. Student services are designed to provide advising, tutoring, virtual job fair attendance, and other activities supporting student completion and employment for both on-ground and online students.

Students receive information throughout the admissions process regarding the cost to attend the University. The information is also publicly available on the University website. The University's Admissions Office and Office of Financial Aid identify potential grants, scholarships, and state plans for each student to reduce potential student debt. The net cost versus gross costs are identified clearly for the student. Students receive advising from

Financial Aid Advisors prior to enrolling in classes for the first time. Admissions personnel, Student Services Counselors and Departmental Chairs advise students of the need for academic readiness as well as the degree requirements. A specific success pathway is developed for each student.

The University's tuition increases have not exceeded 3%. The University also has a tuition guarantee for undergraduates, which means full-time tuition is guaranteed not to increase more that 1% per year at the rate applied at time of enrollment. The tuition remains at this rate if the student remains enrolled full-time without a break in attendance.

The University has in place services and learning tools to guide students to successful degree completion. Programs such as Early Alert provide the University's faculty and staff opportunities for early student intervention on the pathway to graduation. This applies to all students regardless of the mode of course delivery or degree program. Capitol Technology University is also a transfer friendly institution and participates in multiple programs for government and military credit transfer. Capitol Technology University participates in the Articulation System for Maryland Colleges and Universities (ARTSYS) and has multiple transfer agreements with local institutions at all degree levels.

The University has in place services, tutoring, and other tools to help ensure student graduation and successful job placement. The University hosts a career (job) fair twice a year. The University has an online career center available to all students covering such topics as career exploration, resume writing, job search techniques, social media management, mock interviews, and assistance interpreting job descriptions, offers, and employment packages.

The University also works with its advisory boards, alumni, partners, and faculty to help ensure the degrees offered at the University are compatible with long-term career opportunities in support of the state's knowledge-based economy.

Goal 3: Innovation

"Foster innovation in all aspects of Maryland higher education to improve access and student success."

Capitol Technology University's past, present, and future is inextricably intertwined with innovation. The University has a long tradition of serving as a platform for the use of new and transformative approaches to delivering higher education. New technology and cutting-edge techniques are blended with proven strategies with the goal of enabling student success in all classroom modalities as well as in a successful career after graduation. As a small institution, Capitol Technology University has the agility to rapidly integrate new technologies into the curriculum to better prepare students for the work environment. The University designs curriculum in alliance with its accreditation and regulating organizations and agencies.

The University also employs online virtual simulations in a game-like environment to teach the application of knowledge in a practical hands-on manner. The University is engaged with a partner creating high-level virtual reality environments for use by doctoral students pursuing this degree. This use of current technology occurs in parallel with traditional proven learning strategies. These elements of the University's online learning environment are purposeful and intended to improve the learning environment for both the student and faculty

member. In addition, these elements are intentionally designed to increase engagement, improve outcomes, and improve retention and graduation rates. The University believes that innovation is the key to successful student and faculty engagement.

Example: The University engages its students in 'fusion' projects, which allows students to contribute their skills in interdisciplinary projects such as those in our Astronautical Engineering and Cyber Labs. In those labs, students become designers, builders, and project managers (e.g., to send a CubeSAT on a NASA rocket) and data analysts (e.g., to analyze rainforest data for NASA). The University's students recently launched another satellite aboard a NASA rocket from a location in Norway at the beginning of the 2019 Fall Semester. We are also recruiting additional partners for the proposed **Ph.D. in Quantum Computing** for which real-world projects will provide students integrative learning opportunities.

The University also supports prior learning assessment. Portfolio analysis is available. The University accepts professional certifications for credit for specific courses. In addition, the University allows students to take a competency exam for credit for required courses up to the current state limits.

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

1. **1. Describe potential industry or industries, employment opportunities, and expected level of entry (*ex: mid-level management*) for graduates of the proposed program.**

Graduates with the **Ph.D. in Quantum Computing** will be expected to fill executive and senior-level positions in commercial companies as well as local, state, and federal government with a variety of titles such as:

- Quantum Senior Scientist
- Quantum Senior Software Engineer
- Chief, Quantum Computing Solutions
- Vice President, Quantum Solutions
- Senior Director, Quantum Computing
- Senior Quantum Solutions Architect
- Senior Quantum Systems Engineer
- Director, Federal Quantum Research
- Chief, State Quantum Solutions
- Senior State Quantum Applications Engineer
- Senior Director, Financial Quantum Computing

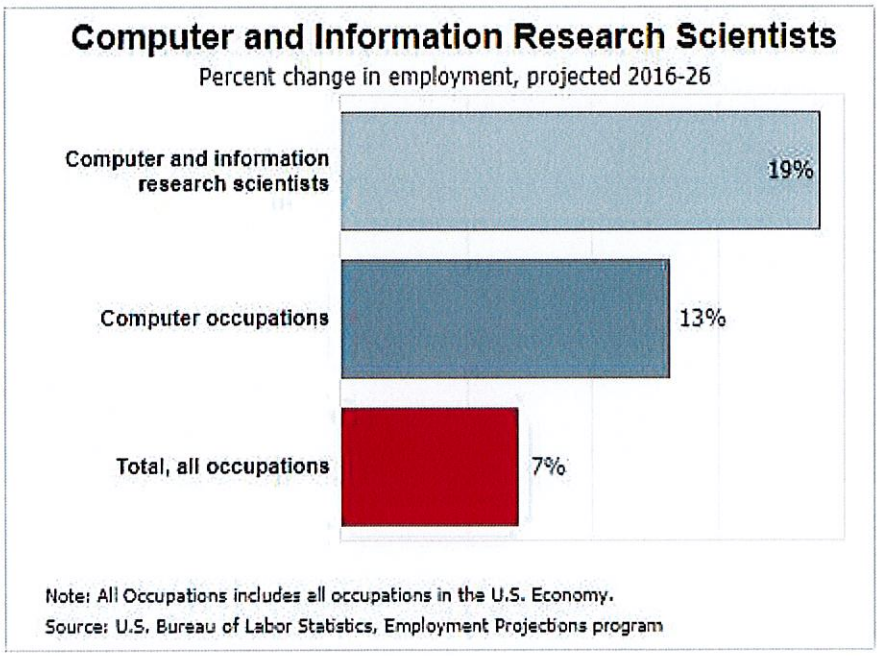
Graduates will also possess the required knowledge in Quantum Computing to serve as a subject matter expert and form their own private company.

Significant advances are being made rapidly in the field of Quantum Computing that is fueling the requirement for more senior Quantum leaders and experts. For example, in late November 2019, MIT researchers devised a novel circuit design that enables precise control of computing with magnetic waves -- no electricity is needed. The advance by MIT researchers takes a step toward practical magnetic-based computing devices; those devices have the potential to compute far more efficiently than using current electronics. This groundbreaking advance is just one of

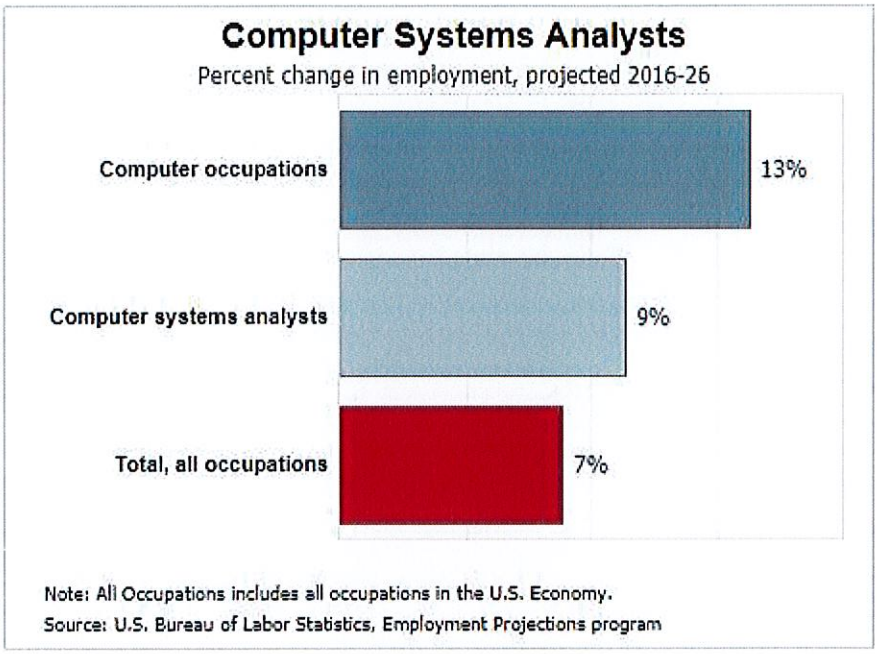
many that occurred in late 2019 and has the potential to revolutionize the use of technology around the world in the near future.

1. **Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program.**

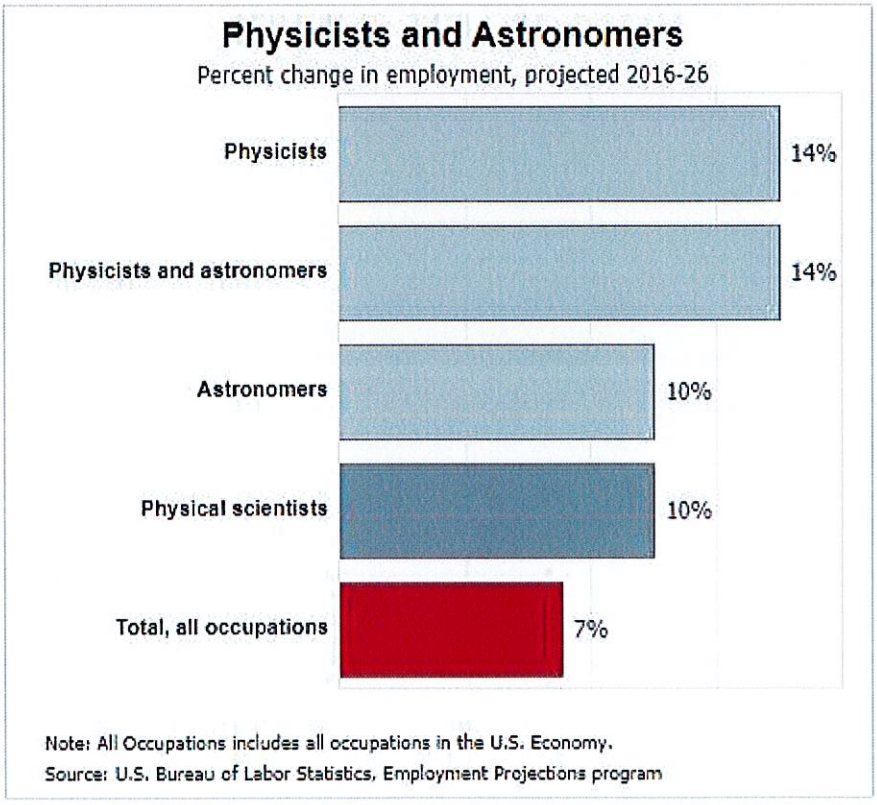
Three major occupational areas: Physics, Computer Science and Engineering Science, can lay claim to the current work in developing Quantum Computing. Based on NCES CIP Codes containing any mention of "quantum" and, additionally, considering that Computer Science, Physics and Engineering Science could also be considered a home for Quantum Computing, the University determined there are three U.S. Bureau of Labor Statistics (BLS) occupations that are representative of the general, growth outlook for the Quantum Computing industry. Those BLS occupations are: Computer and Information Research Scientists, Computer Systems Analysts, and Physicists and Astronomers.



(Source: https://www.bls.gov/ooh/computer-and-information-technology/computer-and-information-research-scientists.htm#tab-6, retrieved 7/15/2019)



(Source: https://www.bls.gov/ooh/computer-and-information-technology/computer-systems-analysts.htm, retrieved 7/15/2019)



(Source: https://www.bls.gov/ooh/life-physical-and-social-science/physicists-and-astronomers.htm, retrieved 7/15/2019)

2. **Discuss and provide evidence of market surveys that clearly provide quantifiable and reliable data on the educational and training needs and the anticipated number of vacancies expected over the next 5 years.**

Quantum computing is a new discipline and market surveys do not exist yet for this field. However, both Congress and the White House have shown major support to developing Quantum Computing.

The National Quantum Initiative Act was signed into law in late 2018. According to the Office of Management and Budget (OMB), and as reported in a 2019 Congressional Research Service (CRS) report on FY2020 technology spending by the federal government, the FY2020 budget includes approximately $430 million for this initiative at DOD, DOE, NIST, and NSF.

In February 2019, the CRS issued a Defense Primer on emerging technologies. Quantum technology was a key item on the list. The CRS stated that Quantum technology "holds significant implications for the future of encryption and stealth technologies." (Source: https://crsreports.congress.gov/product/pdf/IF/IF11105, retrieved 7/15/2019).

The growth of Quantum Computing and growing shortage of talent has been widely reported in mainstream, industry, and academic sources. Wired magazine discussed the growth in quantum computing jobs in a 2018 article. (Source: https://www.wired.com/story/national-quantum-initiative-quantum-computing-jobs/) The New York *Times* published an article stating the next technical talent shortage would be in Quantum Computing. (Source: https://www.nytimes.com/2018/10/21/technology/quantum-computing-jobs-immigration-visas.html) In January 2019, MIT reported a shortage of Quantum Computing talent. (Source: http://news.mit.edu/2019/mit-william-oliver-qanda-talent-shortage-quantum-computing-0123) The growth in Quantum Computing across multiple disciplines has also been cited. Quantum Computing is now being applied to many new areas, including the health care industry, the energy industry, and data analytics, as well as Machine Learning and Artificial Intelligence. (Source for health care: https://blogs.bmj.com/technology/2017/11/03/quantum-computing-and-health-care/, retrieved 7/15/2019) (Source for energy industry: https://qz.com/1566061/quantum-computing-will-change-the-way-the-world-uses-energy/, retrieved 7/15/2019) (Source for data analytics: https://www.pluralsight.com/resource-center/guides/quantum-computing-helping-business, retrieved 7/15/2019). (Source: https://www.technologyreview.com/s/612435/machine-learning-meet-quantum-computing/, retrieved 7/15/2019).

One important development at a Quantum Computing company in Maryland illustrates the explosive growth to come soon in the field. IonQ is a College Park, Maryland-based company that was founded in 2015. IonQ has built two working quantum computers and has expanded its own hiring announcements for a wide variety of Quantum Computing positions. As of late 2019, IonQ – just one small Maryland company -- had listings for 21 new positions. (Source: https://ionq.com/company, retrieved 8/16/2019). A wide range of other companies are also involved in many other Quantum Computing initiatives. At the same time, Quantum Computing companies have become hot merger and acquisition targets; for example, Rigetti recently announced its purchase of QxBranch. (Source: https://www.rigetti.com/, retrieved 8/16/2019). All

of those events help to display the urgent need for educational and training opportunities in the field.

Awaiting new graduates with Quantum Computing expertise, are the following companies that rank among the most prominent firms currently involved in Quantum Computing:

1. IBM
2. Google
3. D-Wave
4. AT&T
5. Atom Computing
6. Accenture
7. Fujitsu
8. HP
9. Honeywell
10. Intel
11. Microsoft
12. Lockheed Martin
13. Northrup Grumman
14. Rigetti Computing/QxBranch
15. QC Ware
16. Raytheon
17. Toshiba
18. Zapata Computing

All of those companies expect significant growth in Quantum Computing and related personnel needs in the near future.

3. Data showing the current and projected supply of prospective graduates.

There are very few higher education institutions in the nation producing graduates with Quantum Computing degrees at any level. There are also no reliable market surveys yet of the current and projected supply prospective graduates with Quantum Computing degrees. However, there are plenty of other indicators of the expanding growth and demand for academically-trained individuals who can become part of the Quantum Computing workforce—indicators from both the federal government and private industry.

Perhaps one of the best indicators of the current and projected demand for graduates is the recent Department of Energy Request for Information (RFI) on establishing Quantum Information Science Centers.

Referring to Quantum Information Science as "QIS", the RFI states:

> The rapid progress in this field promises profound impacts in the coming decades on scientific discovery and technological innovation. In competitive terms, QIS is creating potentially transformative opportunities and technically complex, urgent challenges for the Nation, as growing international interest and investments fuel accelerating global activity in quantum science and technology. These opportunities and challenges demand a long-term, large-scale commitment of U.S. scientific and technological resources to multi-institutional, multidisciplinary efforts that are commensurate with

world leadership in this pivotal field.

(Source: https://www.regulations.gov/document?D=DOE-HQ-2019-0025-0001, retrieved 8/16/2019).

The federal government's new National Quantum Initiative proposes to open several Quantum research hubs around the country, involving various academic institutions and federal agencies such as NIST and NSF.

The employment projections for Quantum Computing related occupations across all industries also reflect very strong growth through 2026.

Employment Projections to 2026 for Quantum Computing Related Occupations

OccupationName	Base (2016)	Proj (2026)	Change	Percent Change (%)	Avg Annual Openings
Computer and Information Research Scientists	27,900	33,200	5,300	19.0	2,500
Computer Systems Analysts	600,500	654,900	54,400	9.1	44,900
Physicists	17,900	20,500	2,600	14.5	1,700

(Source: https://projectionscentral.com/Projections/LongTerm, retrieved 8/16/2019).

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.**

There are no **Doctor of Philosophy (Ph.D.) in Quantum Computing** programs in the State of Maryland. There are four doctoral degrees in the broader related area of computer science at Bowie State University (BSU), Johns Hopkins University (JHU), University of Maryland Baltimore County (UMBC), and University of Maryland College Park (UMCP). Within BSU's Doctor of Science (D.Sc.) in Computer Science, there are no classes focused on Quantum Computing in the core courses or four knowledge areas. Moreover, BSU does not offer a Ph.D. in Quantum Computing. Within JHU's Ph.D. in Computer Science, there are no classes focused on Quantum Computing. JHU also does not offer a Ph.D. in Quantum Computing. Within UMBC's Ph.D. in Computer Science, there two elective courses in Quantum Computing: one elective course in Quantum Computing and one elective course in Quantum Information Science. However, UMBC does not offer a Ph.D. in Quantum Computing. Within UMCP's Ph.D. in Computer Science, there is one elective Ph.D. qualifying course in Quantum Computing: Introduction to Quantum Information Processing. UMCP also allows its Ph.D. in Computer Science students to do research in Quantum Computing if they desire. However, UMCP does not offer a Ph.D. in Quantum Computing. **Capitol Technology University's proposed Doctor of Philosophy (Ph.D.) in Quantum Computing degree program is different; the proposed Ph.D. degree program is solely focused on the area of Quantum Computing.**

2. **Provide justification for the proposed program.**

   The proposed **Ph.D. in Quantum Computing** program is strongly aligned with the University's strategic priorities and is supported by adequate resources. The proposed **Ph.D. in Quantum Computing** degree will strengthen and expand upon existing technology, management, and applied engineering degree programs at the University. In addition, the Quantum Computing doctoral program will be an option for all students as the field integrates well with the market needs of the University's other technical programs. The degree will present the opportunity for the most advanced study in a rapidly changing and highly complex discipline. Research shows a significant shortage of senior Quantum Computing professionals in this rapidly expanding discipline. This program helps fill the gap. There is a thorough discussion of the need in Sections B and C of this document.

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 HBIs.**

   The University does not anticipate any impact on the implementation or maintenance of high-demand programs at HBIs. There are no Doctor of Philosophy (Ph.D.) in Quantum Computing programs in the State of Maryland. At Maryland's HBIs, there is one doctoral degree in the broader related area of computer science at Bowie State University (BSU). Within BSU's Doctor of Science (D.Sc.) in Computer Science, there are no classes focused on Quantum Computing in the core courses or four knowledge areas. Moreover, BSU does not offer a Ph.D. in Quantum Computing. **Capitol Technology University's proposed Doctor of Philosophy (Ph.D.) in Quantum Computing degree program is different; the proposed Ph.D. degree program is solely focused on the area of Quantum Computing.**

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.**

   The University does not anticipate any impact on the uniqueness and institutional identities and missions of HBIs. There are no Doctor of Philosophy (Ph.D.) in Quantum Computing programs in the State of Maryland. At Maryland's HBIs, there is one doctoral degree in the broader related area of computer science at Bowie State University (BSU). Within BSU's Doctor of Science (D.Sc.) in Computer Science, there are no classes focused on Quantum Computing in the core courses or four knowledge areas. Moreover, BSU does not offer a Ph.D. in Quantum Computing. **Capitol Technology University's proposed Doctor of Philosophy (Ph.D.) in Quantum Computing degree program is different; the proposed Ph.D. degree program is solely focused on the area of Quantum Computing.**

G. Adequacy of Curriculum Design, Program Modality, and 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.**

The University's New Programs Group established the proposed program through a rigorous review of unmet needs. The group includes selected representation from the University's faculty, administrators, and Executive Council. The program will be overseen by a diverse faculty with backgrounds in quantum computing, computer science, computer engineering, and astronautical science. Please see Section I for a detailed list of the faculty's backgrounds and qualifications.

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

Educational Objectives:

a. Students will integrate and synthesize alternate, divergent, or contradictory perspectives or ideas fully within the field of Quantum Computing.
b. Students will demonstrate advanced knowledge and competencies in Quantum Computing.
c. Students will analyze existing theories to draw data-supported conclusions in Quantum Computing.
d. Students will analyze theories, tools, and frameworks used in Quantum Computing.
e. Students will execute a plan to complete a significant piece of scholarly work in Quantum Computing.
f. Students will evaluate the legal, social, economic, environmental, and ethical impact of actions within Quantum Computing and demonstrate advanced skill in integrating the results in to the leadership decision-making process.

Learning Outcomes:

Upon graduation:

a. Graduates will integrate the theoretical basis and practical applications of Quantum Computing in to their professional work.
b. Graduates will demonstrate the highest mastery of Quantum Computing.
c. Graduates will evaluate complex problems, synthesize divergent/alternative/contradictory perspectives and ideas fully, and develop advanced solutions to Quantum Computing challenges.
d. Graduates will contribute to the body of knowledge in the study of Quantum Computing.

3. Explain how the institution will:

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

Capitol Technology University will assess student achievement of the learning outcomes per the regulations specified by the University's regional accreditation organization: the Middle States Commission on Higher Education (MSCHE). The University will also evaluate student achievement of the learning outcomes using the Quality Assurance Agency for Higher Education (QAA) Framework for Higher Education Qualifications.

Under MSCHE, the University will use Standard V, Educational Effectiveness Assessment, of the Standards for Accreditation and Requirements of Affiliation. Standard V requires:

Assessment of student learning and achievement demonstrates that the institution's students have accomplished educational goals with their program of study, degree level, the institution's mission, and appropriate expectations for institutions of higher education.

(Source: https://www.msche.org/standards/, retrieved 7/22/2019)

Per the MSCHE's accreditation requirements, Capitol Technology University will measure Standard V by using the following criteria:

An accredited institution possesses and demonstrates the following attributes or activities:

1. clearly stated educational goals at the institution and degree/program levels, which are interrelated with one another, with relevant educational experiences, and with the institution's mission;

2. organized and systematic assessments, conducted by faculty and/or appropriate professionals, evaluating the extent of student achievement of institutional and degree/program goals. Institutions should:

a. define meaningful curricular goals with defensible standards for evaluating whether students are achieving those goals;

b. articulate how they prepare students in a manner consistent with their mission for successful careers, meaningful lives, and, where appropriate, further education. They should collect and provide data on the extent to which they are meeting these goals;
c. support and sustain assessment of student achievement and communicate the results of this assessment to stakeholders;

3. consideration and use of assessment results for the improvement of educational effectiveness. Consistent with the institution's mission, such uses include some combination of the following:

a. assisting students in improving their learning;
b. improving pedagogy and curriculum;
c. reviewing and revising academic programs and support services;
d. planning, conducting, and supporting a range of professional development activities;
e. planning and budgeting for the provision of academic programs and services;
f. informing appropriate constituents about the institution and its programs;
g. improving key indicators of student success, such as retention, graduation, transfer, and placement rates;
h. implementing other processes and procedures designed to improve educational programs and services;

4. if applicable, adequate and appropriate institutional review and approval of assessment services designed, delivered, or assessed by third-party providers; and

5. periodic assessment of the effectiveness of assessment processes utilized by the institution for the improvement of educational effectiveness.

(Source: http://www.msche.org/wp-content/uploads/2018/06/RevisedStandardsFINAL.pdf)

The University will also evaluate student achievement of the learning outcomes using the Quality Assurance Agency for Higher Education (QAA) Framework for Higher Education Qualifications and its related assessment tools. The following tables provide a high-level view of the QAA Qualification Frameworks for doctoral programs:

QAA Qualifications Framework for Ph.D.

4.18 Descriptor for a higher education qualification at level 8 on the FHEQ and SCQF level 12 on the FQHEIS: doctoral degree

The descriptor provided for this level of the frameworks is for any doctoral degree which should meet the descriptor in full. This qualification descriptor should also be used as a reference point for other level 8/level 12 qualifications.

Doctoral degrees are awarded to students who have demonstrated:

- the creation and interpretation of new knowledge, through original research or other advanced scholarship, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication
- a systematic acquisition and understanding of a substantial body of knowledge which is at the forefront of an academic discipline or area of professional practice
- the general ability to conceptualise, design and implement a project for the generation of new knowledge, applications or understanding at the forefront of the discipline, and to adjust the project design in the light of unforeseen problems
- a detailed understanding of applicable techniques for research and advanced academic enquiry.

Typically, holders of the qualification will be able to:

- make informed judgements on complex issues in specialist fields, often in the absence of complete data, and be able to communicate their ideas and conclusions clearly and effectively to specialist and non-specialist audiences
- continue to undertake pure and/or applied research and development at an advanced level, contributing substantially to the development of new techniques, ideas or approaches.

And holders will have:

- the qualities and transferable skills necessary for employment requiring the exercise of personal responsibility and largely autonomous initiative in complex and unpredictable situations, in professional or equivalent environments.

QAA Qualifications Framework for Ph.D. (Continued)

4.18.1 Doctoral degrees are awarded for the creation and interpretation, construction and/or exposition of knowledge which extends the forefront of a discipline, usually through original research.

4.18.2 Holders of doctoral degrees are able to conceptualise, design and implement projects for the generation of significant new knowledge and/or understanding. Holders of doctoral degrees have the qualities needed for employment that require both the ability to make informed judgements on complex issues in specialist fields and an innovative approach to tackling and solving problems.

4.18.3 Doctoral programmes that may have a substantial taught element in addition to the research component (for example, professional doctorates), lead usually to awards which include the name of the discipline in their title (for example, EdD for Doctor of Education or DClinPsy for Doctor of Clinical Psychology). Professional doctorates aim to develop an individual's professional practice and to support them in producing a contribution to (professional) knowledge.

4.18.4 The titles PhD and DPhil are commonly used for doctoral degrees awarded on the basis of original research.

4.18.5 Achievement of outcomes consistent with the qualification descriptor for the doctoral degree normally requires study equivalent to three full-time calendar years.

4.18.6 Higher doctorates may be awarded in recognition of a substantial body of original research undertaken over the course of many years. Typically a portfolio of work that has been previously published in a peer-refereed context is submitted for assessment. Most degree awarding bodies restrict candidacy to graduates or their own academic staff of several years' standing.

(Source: UK Quality Code for Higher Education, Part A: Setting and Maintaining Academic Standards, The Frameworks for Higher Education Qualifications of UK Degree-Awarding Bodies, October 2014)

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

Program description, as it will appear in the catalog:

The **Doctor of Philosophy (Ph.D.) in Quantum Computing** provides students with the opportunity to conduct extensive and sustained original research at the highest level in the field of Quantum Computing. Quantum Computing harnesses and exploits the laws of quantum mechanics to process information. Using the phenomena of superposition and entanglement, a quantum computer can process a vast number of calculations simultaneously. Difficult tasks that were once thought impossible for classical computers can be achieved quickly and efficiently using a Quantum Computing. The **Ph.D. in Quantum Computing** is a unique doctoral program designed to meet the demands of the highest skilled professionals to become the leaders who will be involved in the advancement, expansion, and support of the Quantum Computing field. Quantum Computing is one of the technological arenas that is rapidly expanding with significant advancements occurring regularly. As such, there is a need for innovative researchers and practitioners who desire to elevate their skills to the highest level and contribute to the body of knowledge in Quantum Computing.

The proposed **Ph.D. in Quantum Computing** degree is designed for current professionals in the field. The degree provides a path for Quantum Computing personnel to explore new ground and create technological breakthroughs. The University is in a unique position to provide those students with an avenue to pursue a deep proficiency in this area using an interdisciplinary methodology, cutting-edge courses, and dynamic faculty skill sets. Graduates will contribute significantly to the Quantum Computing field through the creation of new knowledge and ideas. The **Ph.D. in Quantum Computing** program is designed as a doctorate by research where students will quickly become able to engage in research and publishing.

Description of program requirements:

Entrance Requirements

To be accepted into the **Ph.D. in Quantum Computing** program, students must have completed an appropriate master's degree with a cumulative GPA of no less than 3.0 on a 4.0 scale. Students must also possess a high level of experience in the field, or a closely related field, and show the academic promise of their future ability to produce original research of publishable quality (suitable for a scholarly peer-reviewed journal or publication and presentation of high stature).

Students must also provide a prospectus of at least 750 words that details their existing expertise and preparation for success in conducting original research within Capitol Technology University's **Ph.D. in Quantum Computing** program. International students are required to take the TOEFL and score at least 550 on the paper-based test or 79 on the internet-based test.

Degree Requirements:

The **Ph.D. in Quantum Computing** program is designed for students with an appropriate master's degree and significant years of field experience. During the program, students will conduct original research in an approved area of study. Successful completion of the program culminates in the award of the **Doctor of Philosophy (Ph.D.) in Quantum Computing** degree.

There are two options for completion of the **Ph.D. in Quantum Computing** program. Under the thesis option, the student will produce, present, and defend a doctoral dissertation after receiving the required approvals from the student's Committee and the Ph.D. Review Board. Under the publication option, the student will produce, present, and defend their original doctoral research after receiving the required approvals from the student's Committee and the Ph.D. Review Board. The student must also publish three works of original research in a scholarly peer-reviewed journal(s). One of the three published works may be in a peer reviewed conference proceeding.

Degree Requirements:

The following is a list of courses for the **Ph.D. in Quantum Computing** degree. Students expecting to complete this degree must meet all prerequisites for the courses listed below.

Doctor of Philosophy in Quantum Computing
Courses
Total Credits: 60

QUANTUM COMPUTING DOCTORAL CORE: 30 CREDITS

CSQ-800 Quantum Computing Research Background (6 Credits)
The student will focus on the study of the latest Quantum Computing strategies, tactics and developments. The student will synthesize the growing effect of technology on current operations, international relationships and effects on the field, and where there are areas of improvements or failings. The focus will be to start identifying areas for research at a later stage and explore the background. Prerequisite: None.

CSQ-810 Quantum Computing Research Methodologies (6 Credits)
The student will evaluate and develop research methodologies and strategies suitable for understanding Quantum Computing and address the data sources, information, and intelligence to test a hypothesis or research question. It is expected the student will be building upon CSQ-800 in refining and developing their research task and plan. Prerequisite: CSQ-800.

CSQ-820 Quantum Computing Future Demands (6 Credits)
The student will research the future demands in the Quantum Computing industry and how these influence specific research questions. Data collection and applications will be central to evaluating the needs of Quantum Computing on the short, medium and long term. Prerequisite: CSQ-810.

CSQ-830 Strategies for Quantum Computing (6 Credits)
The student will undertake a robust and comprehensive analysis of the strategies for the growth and evolution of the Quantum Computing industry. Students will analyze the influences of technology, economics, international politics, and sustainability that dictate planning based upon non-technical aspects. For example, how international disputes affect key resources, costs, and schedules. Prerequisite: CSQ-820.

CSQ-840 Quantum Computing Research Proposal (6 Credits)
The student will produce a proposal for research that is comprehensive in detail and planning. The proposal will address the research topic, scope and aims, objectives and include a timing plan. The doctoral student will then complete the research milestones according to the proposal and research plan. Prerequisite: CSQ-830.

QUANTUM COMPUTING DOCTORAL RESEARCH AND WRITING: 30 CREDITS

CSQ-900 Quantum Computing Doctoral Writing I (6 Credits)
The student will compose and complete Chapters 1 and 2 within the boundaries of the proposal and research plan. Chapters 1-2 will be reviewed by the student's Chair and Committee and must be approved for the student to advance. Prerequisite: CSQ-840.

CSQ-910 Quantum Computing Doctoral Writing II (6 Credits)
The student will compose and complete Chapter 3 according to the approved proposal. The student will also submit Chapters 1-3 to the Institutional Review Board (IRB) and Academic Review Board (ARB). After receiving the necessary approvals, the student will conduct data collection and analysis activities consistent with the research plan. Prerequisite: CSQ-900.

CSQ-920 Quantum Computing Doctoral Writing III (6 Credits)
The student will compose and complete Chapter 4. The student will provide a complete and substantive presentation of the research results in Chapter 4. The student's Chair and Committee must review and approve Chapter 4 for the student to advance. Prerequisite: CSQ-910.

CSQ-930 Quantum Computing Doctoral Writing IV (6 Credits)
The student will compose and complete Chapter 5 and submit the work to the student's Chair and Committee. The student will also finalize all required elements of their research. The student's Chair and Committee must review and approve the complete document. The student's Chair and Committee will then submit the complete document to the University Reviewers and Ph.D. Review Board for approval. The student must receive approval from the University Reviewers and Ph.D. Review Board to advance forward. Prerequisite: CSQ-920.

CSQ-940 Quantum Computing Doctoral Defense (6 Credits)
Upon approval from the University Reviewers and Ph.D. Review Board, the student will prepare and deliver an oral presentation summarizing the body of research and defend the same through viva voce (i.e., oral examination). The student's Chair, Committee and Ph.D.

Review Board will confer to determine if the student has provided a sufficient and necessary final oral defense of the research. Prerequisite: CSQ-930.

5. **Discuss how general education requirements will be met, if applicable.**

   N/A. This is a graduate program.

6. **Identify any specialized accreditation or graduate certification requirements for this program and its students.**

   The University is accredited regionally by the Middle States Commission in Higher Education (MSCHE) and through four specialized accrediting organizations: International Accreditation Council of Business Education (IACBE), Accreditation Board for Engineering and Technology (ABET), NSA, and DHS. All five accrediting organizations have reviewed the University's distance education program as part of their accreditation process. Capitol Technology University is fully accredited by MSCHE, IACBE, ABET, NSA, and DHS. The University is in good standing with all its accrediting bodies. This program is designed to meet the requirements of the MSCHE.

7. **If contracting with another institution or non-collegiate organization, provide a copy of the written contract.**

   The University will not be contracting with another institution or non-collegiate organization.

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.**

   The **Ph.D. in Quantum Computing** 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.

   Curriculum, course and degree information will be available on the university website and via e-mail as well as regular mail (by request). The expectations on faculty/student interaction are available to students during virtual open house events, literature, website, etc. In addition, this information is part of the material distributed for each course. Students receive guidance on proper behavior/interaction with their Chair and M.S. faculty members as well as the online environment to facilitate a high-level doctoral learning experience. Technology competence and skills and technical equipment requirements are part of the material distributed for each course. The technical equipment requirements are also listed on our website and provided to students in the welcome package.

   The University's academic support services, financial aid resources, costs and payment policies, and Learning Management System are covered in the University Open Houses, application

process, Welcome Aboard process, Orientation, Student Town Halls, and individual counseling.

9. **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.**

   The University will provide students with clear, complete, and timely information on the program's 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.

   Curriculum, course and degree information will be available on the University website and via e-mail as well as regular mail (by request). The expectations on faculty/student interaction are available to students during virtual open house events, literature, website, etc. In addition, this information is part of the material distributed for each course. Students receive guidance on proper behavior/interaction in the online environment to facilitate a high-level learning experience. The required technology competence and skills, plus the technical equipment requirements, are part of the material distributed for each course. The technical equipment requirements are also listed on the University's website and provided to students in the welcome package.

   The University's academic support services, financial aid resources, costs and payment policies, and Learning Management System are covered in the University Open Houses, application process, Welcome Aboard process, Orientation, Student Town Halls, and individual counseling.

H. Adequacy of Articulation:

1. **If applicable, discuss how the program supports articulation with programs at partner institutions. Provide all relevant articulation agreements.**

   This program does not currently have articulation partners in Quantum Computing. However, the articulation process will work as it does for the University's current degrees. The University is very active with its transfer partners throughout the state and beyond. The goal of the University is to work with partners to make transfer as seamless as possible and to maximize the student's transfer credits as allowable. There are University transfer admissions personnel to guide the student through the process.

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

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

   Almost all of the faculty listed below have been engaged with the University for at least several years. Dr. Antunes, Dr. Bajracharya, Dr. Bajwa, Dr. Hosseini, Dr. McAndrew, and Dr. Steele are

fulltime faculty members. All of the faculty members hold terminal degrees. Dr. McAndrew is the Dean of Doctoral Programs. He is supported in this program by five fulltime faculty who are computer science experts: Dr. Antunes, Dr. Bajracharya, Dr. Bajwa, Dr. Hosseini, Dr. McAndrew, and Dr. Steele. All of the faculty have experience with quantum computing and a related science. Dr. Steele is also the Department Head of the Computer Science Department. Dr. Antunes is also the Acting Department Head of the Astronautical Engineering Department. Other appropriately credentialed faculty with multi-disciplinary skills involving quantum computing will be added as needed as part of the delivery process. The University leadership is confident in the quality of the faculty and their abilities to provide a learning environment supportive of the University goals for student success.

Instructors who will be engaged with the **Ph.D. in Quantum Computing** are:

INSTRUCTOR	BACKGROUND	COURSES ALIGNED TO BE TAUGHT
Dr. Alex "Sandy" Antunes Full time	Ph.D. Computational Sciences and Informatics M.S. Astronomy B.S. Astronomy	All CSQ 800 and 900 Series Courses
Dr. Chandra Bajracharya Full time	Ph.D. Electrical and Computer Engineering M.S. Applied Computing M.S. Electrical Power Engineering B.E. Electrical Engineering	All CSQ 800 and 900 Series Courses
Dr. Garima Bajwa Full time	Ph.D. Computer Science and Engineering M.S. Electrical and Computer Engineering B.S. Electronics and Communication Engineering	All CSQ 800 and 900 Series Courses
Dr. Soheil Sadat Hosseini Full time	Ph.D. Engineering, Electrical Engineering & Computer Science M.Sc. Electrical Engineering B.S. Electrical Engineering	All CSQ 800 and 900 Series Courses
Dr. Ian McAndrew Dean, Doctoral Programs Full time	Ph.D. Mechanical Engineering M.Sc. Manufacturing Engineering M.A. Education Management Post-Graduate Diploma in Education B.Sc. (Hons) Mechanical Engineering B.A. Production Engineering	CSQ-840, CSQ-940
Dr. Robert Steele Full time	Ph.D. Computer Science BSc (Honors) Computer Science BSc Math and Computer Science	All CSQ 800 and 900 Series Courses

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

a) Pedagogy that meets the needs of the students

The primary pedagogy for faculty at Capitol Technology University is the Active Learning model. The university believes strongly in a highly-interactive, thinking, and hands-on experience for students in each class to the maximum extent possible.

> It was two Missouri State professors, historian Charles Bonwell and psychologist James Eison, who coined the term "active learning." In their 1991 book on the subject, Active Learning: Creating Excitement in the Classroom, they offered this definition of the concept: "active learning involves students in doing things and thinking about the things they are doing."
>
> The definition, though it seems circuitous, marks a definitive pedagogical shift in college teaching and learning. Rather than think about what they are watching, hearing, or reading, students are first encouraged to be "doing" something in class, and then to apply critical thought and reflection to their own classroom work and activity. Their argument was backed up by research. Even Bligh, 20 years earlier, had pointed out that the immediate rehearsal of new information and knowledge had a significant impact upon learning.
>
> This approach is as helpful in the sciences as it is in the arts or humanities: whether it's organic chemistry, creative writing, or behavioral economics, concepts are all best understood through repeated practice and open, social exploration. The central tenet of active learning is that practice matters, and that classroom time is better spent giving students opportunities to work with concepts over and over, in a variety of ways and with opportunities.
>
> The central tenet of active learning — that practice and interaction matters— can be applied across disciplines for immediate feedback, so that knowledge can take hold in their own minds.
>
> (Source: Preville, P. Active Learning: The Perfect Pedagogy for the Digital Classroom: An Essential Guide for the Modern Professor)

All faculty receive regular periodic and recurring pedagogical training during the academic year. Those training sessions occur in a hybrid format – simultaneously live online and live on-ground in the classroom. The sessions are designed to reach all faculty, both fulltime and adjunct, in order to ensure everyone receives the training. Additionally, the sessions are recorded for those faculty who are unable to attend the live training session due to other professional and teaching commitments.

b) The Learning Management System

The University's Department of Online Learning and Information Technology Division support the online program needs of faculty and students. The Department of Online Learning and the IT Help Desk provide 24-hour support to the faculty. Canvas is the University's online Learning Management System. When a new faculty member is assigned to teach an online course, the Department of Online Learning provides formal training for the instructor. New

faculty are assigned an experienced faculty mentor to ensure a smooth transition to the online environment as well as to ensure compliance with the institution's online teaching pedagogy. The University believes this provides the highest-level learning experience for the faculty member and, in turn, students attending online classes.

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

Faculty at Capitol Technology University receive training in Keller's ARCS Motivational Model and his associated strategies for distance education/online learning.

> A model used in online delivery of teaching and learning to increase learner motivation is the Keller's ARCS motivational model. This model has been considered an important element in online education because of its implications on increased learner motivation and learning outcomes. The Keller's model consists of motivating students by maintaining and eliciting attention (A), such as virtual clinical simulations; making the content and format relevant (R), by modeling enthusiasm or relating content to future use; facilitating student confidence (C), by providing "just the right challenge"; and promoting learner satisfaction (S), by providing reinforcement and praise when appropriate. Examples of the Keller's model include increasing motivation including the arousal of curiosity of students, making the connection between learning objectives and future learning goals, autonomous thinking and learning, and fostering student satisfaction. Keller's ARCS model has been researched by various educational online programs to analyze student motivation and learning outcomes. The Keller's model serves as an example and guide for instructors to motivate and increase online engagement with their students as wells as research purposes.
>
> A qualitative study by Chan Lin investigated online student learning and motivation. Discussion boards, student projects, and reflection data were collected and analyzed from a 12-week web-based course. Respondents indicated the importance of online feedback from the instructor and peer modeling of course tasks to visualize learning progress. The study revealed using Keller's ARCS strategies fosters greater student online engagement by fostering self-efficacy and a sense of accomplishment.
>
> In a mixed method study, assessing the use of Keller's ARCS on instructional design, the use of educational scaffolding fostered positive levels of student motivation. Relevancy, attention, confidence, and satisfaction were all common factors associated with student success in the course and course completion.
>
> (Source: Pinchevsky-Font T, Dunbar S. Best Practices for Online Teaching and Learning in Health Care Related Programs. The Internet Journal of Allied Health Sciences and Practice. January 2015. Volume 13 Number 1.)

All faculty receive regular periodic and recurring training on evidence-based practices for distance education/online learning during the academic year. Those training sessions occur in multiple formats: asynchronous, synchronous (i.e., live online), hybrid (i.e., simultaneously live online and live on-ground), and on-ground in the classroom. The sessions are designed to reach all faculty, both fulltime and adjunct, to ensure all members receive the training. Additionally, the live sessions are recorded for those faculty who are unable to attend the live training session due

to other professional commitments or who are teaching classes at the training delivery time.

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

1. **Describe the library resources available and/or the measures to be taken to ensure resources are adequate to support the proposed program. If the program is to be implemented within existing institutional resources, include a supportive statement by the President for library resources to meet the program's needs.**

   Library Services: The Puente Library offers extensive services and a wide collection for Capitol Technology University students to be academically successful. Library resources are available digitally. The library also provides a mailing service for materials borrowed through the Maryland system. The library is currently supporting the following degrees at the undergraduate level: B.S. in Astronautical Engineering, B.S. in Business Analytics and Data Science, B.S. in Computer Engineering, B.S. in Computer Engineering Technology, B.S. in Computer Science, B.S. in Construction Management and Critical Infrastructure, B.S. in Construction Safety, B.S. in Cyber Analytics, B.S. in Cybersecurity, B.S. in Electrical Engineering, B.S. in Electrical Engineering Technology, B.S. in Engineering Technology, B.S. in Facilities Management and Critical Infrastructure, B.S. in Information Technology, B.S in Management of Cyber and Information Technology, B.S. in Mechatronics Engineering, B.S. in Mechatronics and Robotics Engineering Technology, B.S. in Software Engineering, and B.S. in Technology and Business Management, and B.S in Unmanned and Autonomous Systems. The library is currently supporting the following degrees at the graduate level: M.S. in Aviation, M.S. in Aviation Cybersecurity, M.S. in Computer Science, M.S. in Critical Infrastructure, M.S. in Cyber Analytics, M.S. in Cybersecurity, M.S. in Engineering Technology, M.S. in Information Systems Management, M.S. in Internet Engineering, M.S. in Unmanned and Autonomous Systems Policy and Risk Management, M.B.A., T.M.B.A. Business Analytics and Data Science, T.M.B.A. in Cybersecurity, D.Sc. in Cybersecurity, Ph.D. in Artificial Intelligence, Ph.D. in Aviation, Ph.D. in Business Analytics and Decision Sciences, Ph.D. in Construction Science, Ph.D. in Critical Infrastructure, Ph.D. in Manufacturing, Ph.D. in Occupational Health and Safety, Ph.D. in Product Management, Ph.D. in Technology, Ph.D. in Technology/M.S. in Research Methods Combination Program, and Ph.D. in Unmanned Systems Applications. Therefore, the library is fully prepared to support a **Ph.D. in Quantum Computing.**

   Services provided to online students include:

   - "Ask the Librarian"
   - Research Guides
   - Tutorials
   - Videos
   - Online borrowing

   The John G. and Beverley A. Puente Library provides access to management, decision science, and research methods materials through its 10,000-title book collection, e-books, and its 90 journal subscriptions. The library will continue to purchase new and additional materials in the management, decision science, and research methods area to maintain a strong and current collection in this subject area. Students can also access materials through the library's participation in Maryland's Digital eLibrary Consortium. This online electronic service provides access to numerous databases (Access Science, NetLibrary) that supply students with the

materials they need. Available databases include ProQuest, EBSCO, ACM, Lexis Nexis, Taylor Francis, and Sage Publications.

The Puente Library can provide access to historical management and decision science materials through its membership in the Maryland Independent College and University Association (MICUA) and the American Society of Engineering Education (ASEE). Reciprocal loan agreements with fellow members of these organizations provide the library access to numerous research facilities that house and maintain archives of management and decision science documents. The proximity of the University of Maryland, College Park and other local area research and academic libraries provide the Puente Library with quick access to these materials as well.

The library currently supports the needs students at the undergraduate, masters and doctoral levels.

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

1. **Provide an assurance that the 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. If the program is to be implemented within existing institutional resources, include a supportive statement by the President regarding adequate equipment and facilities to meet the program's needs.**

   No new facilities are required for the program. The online class platform is web based and requires no additional equipment for the institution. The current Learning Management System, Canvas and Zoom, meets the needs of the degree program. The Business and Technology lab, Computer Science Lab, Cyber Lab, Robotics Lab, and Unmanned Systems Lab together meet the potential research needs of the students. The labs provide both local and virtual support.

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

   Capitol Technology University provides an institutional electronic mailing system to all students and faculty. The capability is provided to all students and faculty in all the institution's modalities of course delivery. Capitol Technology University students and faculty are required to use the institution's email addresses (e.g., xxxxxxxx@captechu.edu) in all University matters and communications. The University uses the email capabilities in Microsoft Office 365 and Microsoft Outlook.

   b. A Learning Management System that provides the necessary technological support for distance education

   Capitol Technology University provides a robust Learning Management Systems (LMS) through the use of the Canvas LMS by Instructure (www.canvaslms.com). The University pairs Canvas with Zoom (zoom.us) to provide a platform for every student and faculty member to meet face-to-

face in a synchronous "live" mode of communication. The use of Canvas is required for every course offered at the University; as a result, every course has a classroom on Canvas and Zoom. All syllabi, grades, and assignments must be entered in to Canvas on a timely basis throughout the semester.

Canvas provides the world's most robust LMS. It is a 21st Century LMS; Canvas is a native cloud, Amazon Web Service hosted system. The system is adaptable, reliable, and customizable. Canvas is easy to use for students and faculty. The system is fully mobile and has proven to be timesaving when compared to other systems. The following list provides the features of the system:

Time and Effort Savings

- CANVAS DATA
  Canvas Data parses and aggregates more than 280 million rows of Canvas usage data generated daily.
- CANVAS COMMONS
  Canvas Commons makes sharing a whole lot easier.
- SPEEDGRADER ANNOTATIONS
  Preview student submissions and provide feedback all in one frame.
- GRAPHIC ANALYTICS REPORTING ENGINE
  Canvas Analytics help you turn rich learner data into meaningful insights to improve teaching and learning.
- INTEGRATED MEDIA RECORDER
  Record audio and video messages within Canvas.
- OUTCOMES
  Connect each learning outcome to a specific goal, so results are demonstrated in clearly measurable ways.
- MOBILE ANNOTATION
  Open, annotate, and submit assignments directly within the Canvas mobile app.
- AUTOMATED TASKS
  Course management is fast and easy with automated tasks.
- NOTIFICATION PREFERENCES
  Receive course updates when and where you want - by email, text message, even Twitter or LinkedIn.
- EASE OF USE
  A familiar, intuitive interface means most users already have the skills they need to navigate, learn, and use Canvas.
- IOS AND ANDROID
  Engage students in learning anytime, anywhere from any computer or mobile device with a Web-standard browser.
- USER-CUSTOMIZABLE NAVIGATION

Canvas intelligently adds course navigation links as teachers create courses.

- RSS SUPPORT
  Pull feeds from external sites into courses and push out secure feeds for all course activities.
- DOWNLOAD AND UPLOAD FILES
  Work in Canvas or work offline—it's up to you.
- SPEEDGRADER
  Grade assignments in half the time.

Student Engagement

- ROBUST COURSE NOTIFICATIONS
  Receive course updates when and where you want—by email, text message, and even Facebook.
- PROFILE
  Introduce yourself to classmates with a Canvas profile.
- AUDIO AND VIDEO MESSAGES
  Give better feedback and help students feel more connected with audio and video messages.
- MULTIMEDIA INTEGRATIONS
  Insert audio, video, text, images, and more at every learning contact point.
- EMPOWER GROUPS WITH COLLABORATIVE WORKSPACES
  By using the right technologies in the right ways, Canvas makes working together easier than ever.
- MOBILE
  Engage students in learning anytime, anywhere from iOS or Android, or any mobile device with a Web-standard browser.
- TURN STUDENTS INTO CREATORS
  Students can create and share audio, video, and more within assignments, discussions, and collaborative workspaces.
- WEB CONFERENCING
  Engage in synchronous online communication.
- OPEN API
  With its open API, Canvas easily integrates with your IT ecosystem.
- BROWSER SUPPORT
  Connect to Canvas from any Web-standard browser.
- LTI INTEGRATIONS
  Use the tools you want with LTI integrations.
- MODERN WEB STANDARDS
  Canvas is built using the same Web technologies that power sites like Google, Facebook, and Twitter.

Lossless Learning

- CANVAS POLLS
  Gauge comprehension and incorporate formative assessment without the need for "clicker" devices.
- MAGICMARKER
  Track in real-time how students are performing and demonstrating their learning.
- QUIZ STATS
  Analyze and improve individual assessments and quiz questions.
- LEARNING MASTERY FOR STUDENTS
  Empower students to take control of their learning.

(Source: https://www.canvaslms.com/higher-education/features)

Capitol Technology University has been using Canvas for over four years. Canvas has proven to be a completely reliable LMS system that provides the necessary technological support for distance education/online learning.

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

1. **Table 1: Resources. Finance data for the first five years of the program implementation**

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 below)	$144,666	$296,460	$455,868	$657,324	$833,310
a. Number of F/T Students	0	0	0	0	0
b. Annual tuition/Fee rate	$0	$0	$0	$0	$0
c. Total F/T Revenue (a x b)	$0	$0	$0	$0	$0
d. Number of P/T Students	9	18	27	38	47
e. Credit Hour Rate	$893	$915	$938	$961	$985
f. Annual Credit Hour	18	18	18	18	18
g. Total P/T Revenue (d x e x f)	$144,666	$296,460	$455,868	$657,324	$833,310
3. Grants, Contracts and Other External Sources	0	0	0	0	0
4. Other Sources	0	0	0	0	0
TOTAL (Add 1 – 4)	$144,666	$296,460	$455,868	$657,324	$833,310

A. Provide a narrative rationale for each of the resource categories. If resources have been or will be reallocated to support the proposed program, briefly discuss those funds.

1. Reallocated Funds

The University will not need to reallocate funds for the program.

2. Tuition and Fee Revenue

Tuition is calculated to include an annual 2.5% tuition increase. A 20% attrition rate has been calculated.

3. Grants and Contracts

There are currently no grants or contracts.

4. Other Sources

There are currently no other sources of funds.

5. Total Year

No additional explanation or comments needed.

2. **Table 2: Program Expenditures. Finance data for the first five years of program implementation.**

TABLE 2: EXPENDITURES

Expenditure Category	Year 1	Year 2	Year 3	Year 4	Year 5
1. Faculty (b + c below)	$74,000	$184,500	$226,937	$310,147	$397,374
a. #FTE	1	2.5	3	4	5
b. Total Salary	$60,000	$153,750	$189,114	$258,456	$331,145
c. Total Benefits (20% of salaries)	$12,000	$30,750	$37,823	$51,691	$66,229
2. Admin Staff (b + c below)	$4,942	$5,090	$5,243	$5,374	$6,464
a. #FTE	.07	.07	.07	.07	.07
b. Total Salary	$4,084	$4,207	$4,333	$4,441	$5,508
c. Total Benefits	$858	$883	$910	$933	$956
3. Support Staff (b + c below)	$57,475	$87,638	$119,772	$153,460	$188,755
a. #FTE	1.00	1.5	2	2.5	3
b. Total Salary	$47,500	$73,032	$99,810	$127,883	$157,296
c. Total Benefits	$9,975	$14,606	$19,962	$25,577	$31,459
4. Technical Support and Equipment	$540	$1,170	$1,890	$2,850	$3,760
5. Library	$0	$0	$0	$0	$0
6. New or Renovated Space	$0	$0	$0	$0	$0
7.Other Expenses	$1,170	$5,220	$10,530	$18,620	$27,730
TOTAL (ADD 1-7)	$138,127	$283,618	$364,372	$490,451	$624,083

A. Provide a narrative rationale for each expenditure category. If expenditures have been or will be reallocated to support the proposed program, briefly discuss those funds.

a. Faculty

Table 2 reflects the faculty hours in total, but this does not necessarily imply that these are new hire requirements.

b. Administrative Staff

Capitol Technology University will continue with current the administrative staff through the proposed time period.

c. Support Staff

Capitol Technology University will add additional support staff to facilitate the program.

d. Equipment

Software for courses is available free to students or is freeware. Additional licenses for the LMS will be purchased by the University at the rate of $60 per student in Year 1. The rate is estimated to increase by $5 per year.

e. Library

Money has been allocated for additional materials to be added to the on campus and virtual libraries to ensure the literature remains current and relevant. However, it has been determined that the current material serves the needs of this degree due to the extensive online database.

f. New or Renovated Space

No new or renovated space is required.

g. Other Expenses

Funds have been allocated for office materials, travel, professional development, course development, marketing, and additional scholarships.

h. Total Year

No additional explanation or comments needed.

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.

The assessment process at the University consists of a series of events throughout the Academic Year. The results of each event are gathered by the University Assessment Team and stored in Canvas for analysis and use in annual reports, assessments, etc. The University Assessment Team analyzes the results, develops any necessary action plans, and monitors implementation of the action plans.

Academic Year Assessment Events:

Fall Semester:

- At the August Faculty Retreat, the faculty reviews any outstanding student learning challenges that have not been adequately addressed. The issues are brought to the Academic Deans for review and development of implementation plans.

- Faculty submit performance plans consistent with the mission and goals of the University and department. The documents are reviewed and approved by the Academic Deans.
- Department Chairs and Academic Deans review the Graduating Student Survey data.
- Department Chairs and Academic Deans review student internship evaluations.
- Department Chairs and Academic Deans review grade distribution reports from the spring and summer semesters.
- Department Chairs and Academic Deans review student course evaluations from the Summer Semester.
- Departments conduct Industrial Advisory Board meetings to review academic curriculum recommendations. The Advisory Board meets to begin curriculum review or address special issues that may arise related to curriculum. Based on an analysis and evaluation of the results, the Academic Deans, faculty and the advisory boards will develop the most effective strategy to move the changes forward.

    - NOTE: A complete curriculum review for degrees occurs every 2 years. In most cases, the changes only require that the Academic Deans inform the University President and provide a report that includes a justification and the impact of the changes as well as a strategic plan. Significant changes normally require the approval of the Executive Council.

- The Academic Deans attend the Student Town Hall and review student feedback with Department Chairs.
- Department Chairs conduct interviews with potential employers at our Career Fair.
- Post-residency, the Academic Deans meet with the faculty to review the student learning progress and discuss needed changes.

Spring Semester:

- Faculty Performance Plans are reviewed with faculty to identify issues of divergence and to adjust the plan as needed.
- Department Chairs and Academic Deans review grade distribution reports from the Fall Semester.
- Department Chairs and Academic Deans review the Graduating Student Survey data.
- Department Chairs and Academic Deans review student course evaluations from the Fall Semester and the Spring Semester (in May before the Summer Semester begins).
- Department Chairs and Academic Deans meet to review the content of the graduating student, alumni, and course surveys to ensure the surveys continue to meet the university's assessment needs.
- At Annual Faculty Summit in May, the faculty review and discuss student learning challenges from the past academic year and provide recommendations to the Academic Deans for review and development of implementation plans.
- Department Chairs conduct interviews with potential employers at our Career Fair.
- Departments conduct Industrial Advisory Board meetings to review academic curriculum recommendations.

In addition to these summative assessments, the Academic Deans meet with the Department Chairs on a weekly basis to review current student progress. This formative assessment allows for immediate minor changes, which increase faculty effectiveness and, ultimately, student outcomes.

The Faculty Senate meets monthly during August through April. The Faculty Senate addresses issues that impact student outcomes as those issues emerge. The leadership of the Faculty Senate then provides a report on the matter to the Academic Deans. The report may include a recommendation or a request to move forward with a committee to further examine the issue. In most cases, the changes only require the Academic Deans to inform the University President and provide a report that includes a justification and the impact of changes as well as a strategic plan. Significant changes normally require the approval of the Executive Council.

1. **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.**

Student Learning Outcomes:

Student learning outcomes for the proposed **Ph.D. in Quantum Computing** will be measured using the instruments identified in Section G and Section M as well as the assigned rubrics and assessment measures (e.g., competency exams/projects, case study exams) dictated by the accreditation requirements of the University's regional accreditor [i.e., Middle States Commission in Higher Education (MSCHE)] and our degree specific accrediting organizations (i.e., IACBE, ABET, NSA, DHS). This program is designed to meet the requirements of MSCHE. The University will also evaluate student achievement of the learning outcomes using the UK Quality Assurance Agency for Higher Education (QAA) Framework for Higher Education Qualifications and its related assessment tools. The University is in good standing with all its accrediting bodies.

Student Retention:

The University maintains a comprehensive student retention program under the Vice President for Student Engagement. The program assesses student retention at all levels, including the individual course, major, and degree. During the semester and term, the University's Drop-Out Detective capability, within its Learning Management System (i.e., Canvas), provides an early alert at the course level to potential issues related to retention. Within the Office of Student Life, Academic Advisors monitor Drop-Out Detective and contact students who appear to have issues affecting their academic performance. The Academic Advisors work with each student to create a plan to remove any barriers to success. The Academic Advisors also work with the course instructors as needed to gain additional insight that may be helpful to correcting the situation.

Each student also meets with their Academic Advisor each semester to evaluate their progress toward degree completion. An updated plan of action is developed for each student for their next semester's registration and each succeeding semester through degree completion.

The Vice President for Student Engagement also meets on a regular basis with the Vice President of Academic Affairs and Academic Deans to review the student retention within each degree program and address any issues that appear to be impediments to degree completion.

Student and Faculty Satisfaction:

Evaluations and assessment of Student and Faculty satisfaction occur every semester. Faculty members are evaluated every semester by students enrolled in their courses. Students are required to complete a course evaluation online within a specified time frame at the end of the semester for

every enrolled course or they are locked out of Canvas (the University's Learning Management System) until they complete each survey. Every faculty member is also required to review each of their courses for the semester.

The Department Chairs and Academic Deans review the student evaluations for every course offered at the university. The Department Chairs and Academic Deans also review faculty satisfaction every semester. If changes are needed at the course level, the changes are developed and implemented by the faculty responsible for the courses upon approval of the Academic Deans. If changes are needed at the faculty level, the Department Chairs will make the changes. At the end of this cycle, an evaluation is repeated and the results are analyzed with the appropriate stakeholders regarding the effectiveness of the changes. This is an ongoing process

Cost Effectiveness:

Based on the year-long inputs, evaluations, and reviews described in Section M.1 from faculty, students, industry representatives, and Department Chairs, the University Academic Deans prepare the proposed academic budget for each program for the upcoming year. Budget increases are tied to intended student learning improvements and key strategic initiatives.

Each academic program is also monitored by the Interim Vice President for Finance and Administration throughout every semester and term for its cost effectiveness. Additionally, the revenue and costs of every University program are reviewed annually by the Executive Council and Board of Trustees prior to approving the next year's budget.

N. Consistency with the State's Minority Student Achievement goals (as outlined in COMAR 13B.02.03.05 and in the State Plan for Post-Secondary Education):

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

   Capitol Technology University is a majority/minority school. Our programs attract a diverse set of students who are multiethnic and multicultural. The University actively recruits minority populations for all undergraduate and graduate level degrees. Special attention is also provided to recruit females into the STEM and multidisciplinary programs at all degree levels – undergraduate, master's, and doctoral. The same attention will be given to the **Ph.D. in Quantum Computing.**

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.**

   This program is not associated with a low productivity program identified by the Commission.

P. Adequacy of Distance Education Programs (as outlined in COMAR 13B.02.03.22)

1. **Provide affirmation and any appropriate evidence that the institution is eligible to provide Distance Education.**

   Capitol Technology University is fully eligible to provide distance education. The University has a long history of providing high-quality distance education. The University is accredited regionally by the Middle States Commission in Higher Education (MSCHE) and through four specialized accrediting organizations: International Accreditation Council of Business Education (IACBE), Accreditation Board for Engineering and Technology (ABET), NSA, and DHS. All five accrediting organizations have reviewed the University's distance education program as part of their accreditation process. Capitol Technology University is fully accredited by MSCHE, IACBE, ABET, NSA, and DHS. The University is in good standing with all its accrediting bodies.

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

   Capitol Technology University has a long history of providing high quality distance education/online learning that complies with the Council of Regional Accrediting Commissions (C-RAC) Interregional Guidelines for the Evaluation of Distance Education. The University will also continue to comply with the C-RAC guidelines with the proposed **Ph.D. in Quantum Computing program**.

   a. **Council of Regional Accrediting Commissions (C-RAC) Interregional Guidelines for the Evaluation of Distance Education.**

      1. **Online learning is appropriate to the institution's mission and purposes.**

         Online learning is consistent with the institution's mission, purpose and history. Please refer to Section A of this proposal.

      2. **The institution's plans for developing, sustaining, and, if appropriate, expanding online learning offerings are integrated into its regular planning and evaluation processes.**

         All programs at the University – online, hybrid, and on-ground – are subject to the same regular planning, assessment, and evaluation processes. Please see Section M of this proposal for the detailed process.

      3. **Online learning is incorporated into the institution's systems of governance and academic oversight.**

         All programs at the University – online, hybrid, and on-ground – are subject to the same regular planning, assessment, and evaluation processes. Please see Section M of this proposal for the detailed process.

      4. **Curricula for the institution's online learning offerings are coherent, cohesive, and comparable in academic rigor to programs offered in traditional instructional formats.**

Online programs/courses meet the same accreditation standards, goals, objectives, and outcomes as traditional instruction at the University. The online course development process incorporated the Quality Matters research-based set of standards for quality online course design to ensure academic rigor of the online course is comparable to the traditionally offered course. The University Academic Deans, chairs, and faculty review curriculum annually. Courses are reviewed at the end of each term of course delivery. This process applies to online and traditional courses. In addition, advisory boards are engaged in the monitoring of course quality to ensure quality standards are met regardless of the delivery platform.

5. **The institution evaluates the effectiveness of its online learning offerings, including the extent to which the online learning goals are achieved, and uses the results of its evaluations to enhance the attainment of the goals.**

   Online programs/courses meet the same accreditation standards, goal, objectives, and outcomes as traditional classroom delivery. Learning platforms are chosen to ensure high standards of the technical elements of the course. The University Academic Deans monitor any course conversion from in-class to online to ensure the online course is academically equivalent to traditionally offered course and that the technology is appropriate to support the expected rigor and breadth of the programs courses.

6. **Faculty responsible for delivering the online learning curricula and evaluating the students' success in achieving the online learning goals are appropriately qualified and effectively supported.**

   The Department of Doctoral Programs, where this degree will be sponsored, is staffed by a qualified University Academic Dean, Dr. Ian McAndrew. Dr. McAndrew is the Dean of the Doctoral Program. He is supported in this program by five fulltime faculty who are computer science experts: Dr. Antunes, Dr. Bajracharya, Dr. Bajwa, Dr. Hosseini, Dr. McAndrew, and Dr. Steele. All of the faculty have experience with quantum computing and a related science. Dr. Steele is also the Department Head of the Computer Science Department. Dr. Antunes is also the Acting Department Head of the Astronautical Engineering Department. Other appropriately credentialed faculty with multi-disciplinary skills involving quantum computing will be added as needed as part of the delivery process.

   The evaluation of the courses in the program will be done using the same processes as all other programs at the University. (Please see Section M.) All Capitol Technology University faculty teach in the traditional classroom environment and online. (Please see faculty qualifications in Section I of this document.)

7. **The institution provides effective student and academic services to support students enrolled in online learning offerings.**

   Students can receive assistance in using online learning technology via several avenues. Student aides are available to meet with students and provide tutoring support in both subject matter and use of the technology. Tutors are available in live real-time sessions using Zoom or other agreed upon tools. Pre-recorded online tutorials are also available.

In addition to faculty support, on ground and online tutoring services are available to students in a one-on-one environment.

Laboratories (on ground and virtual) are available for use by all students and are staffed by faculty and tutoring staff who provide academic support.

Library services and resources are appropriate and adequate. Please refer to Section J of this document and the attached letter from the University President. The library adequately supports the students learning needs.

8. **The institution provides sufficient resources to support and, if appropriate, expand its online learning offerings.**

   The University has made the financial commitment to the program (please refer to Section L). The University has a proven record of accomplishment in supporting degree completion.

9. **The institution assures the integrity of its online offerings.**

   Current faculty serve on internal advisory boards that examine possible for program changes, including course and program development. All faculty are selected on domain expertise and program-related teaching experience.

   When new faculty or outside consults are necessary for the design of courses offered, the University's Human Resource Department initiates a rigorous search and screening process to identify appropriate faculty to design and teach online courses. Again, all faculty are selected on domain expertise and program-related teaching experience

   The University online platforms offer several avenues to support instructors engaged in online learning. The Director of Online Learning Division is highly skilled and trained in faculty development. Several seminars and online tutorials are available to the faculty every year. Mentors are assigned to new faculty. Best practice sharing is facilitated through the Academic Deans, Department Chairs, and formal meetings.

   The assessment for online learning classes/students is the same as for all academic programs at the University. Faculty provide required data on student achievement. The Learning Management System provides data on student achievement. Proof of these assessments is available during the class and following class completion to the Academic Deans and Department Chairs. On an annual basis, the information is reported to the University's accreditation authorities such as MSCHE and NSA/DHS.