# Program Development in Quantum Information Science (QIS) and Quantum Computing (QC)

## Office of the Provost and Executive Vice President
## Mississippi State University

*(Submitted: 6/14/2021 by Jamie Dyer)*

## I. Mission and Charge statement

Quantum Information Science (QIS) and Quantum Computing (QC) are rapidly evolving disciplines with wide-ranging applications, and the US is investing billions in advancing QIS/QC. Mississippi State University is a leading institution in research related to these disciplines, and there currently exists a unique window of opportunity to leverage this capacity to develop innovative transdisciplinary academic programs and collaborative research within these fields of study. In Spring 2020, the Provost's Office initiated a series of taskforces to focus on future opportunities for MSU, with topics including transdisciplinary programs, student success, recruiting, and more; therefore, given this opportunity we should challenge ourselves to be a leader in QIS/QC education and research.

Vice Presidents David Shaw, Julie Jordan, and Keith Coble charged the Quantum Task Force (QuTF) to explore how MSU can best fulfill its land-grant mission of teaching, research, and service through the development and implementation of comprehensive transdisciplinary programs in the field of QIS and QC. The following individuals served as core members of the QuTF, and were directly involved in the development of the recommendations presented in this document:

Chair: Dr. Jamie Dyer, Provost 's Office (Geoscience, Professor)

- Amin Amirlatifi — Chemical Engineering, Assistant Professor
- Trey Breckenridge — $HPC^2$ Director
- Katie Echols — ORED
- Steve Grice — NSPARC Director
- Steven Gwaltney — Chemistry, Professor
- Samee Khan — ECE, Professor and Head
- Seong-Gon Kim — Physics and Astronomy, Professor and Director CCS
- Yaroslav Koshka — ECE, Professor and Chair BCoE Working Group on QIS
- Mark Novotny — Physics and Astronomy, Professor and Head, CCS
- Shahram Rahimi — CSE, Professor and Head
- Gautam Rupak — Physics and Astronomy, Professor, CCS

The QuTF, led by Drs. Novotny, Rahimi, and Khan and chaired by Dr. Jamie Dyer, hereby extended the following charges:

1. Identify existing MSU strengths, capabilities, and interest in QIS/QC.

2. Develop a description of potential opportunities related to QIS/QC in terms of grantsmanship and research, from both departments and research centers/institutes.
3. Develop a description of potential opportunities related to QIS/QC in terms of academic programs.
4. Define potential curriculum structures and content based on existing and potential MSU course offerings relevant to QIS/QC.
5. Identify existing and anticipated challenges in advancing MSU's opportunities in QIS/QC.

## II. Recommendations

The QuTF has identified a number of recommendations, outlined below, focused on development of both academic and research programs and opportunities at MSU. Each recommendation is defined by a priority level and an approximate time to completion. Priority does not imply importance, only the order in which these recommendations should be addressed, while the time to completion defines the approximate time period required to realize the recommendation: short (< 1 year), medium (1-2 years), long (> 2 years). While academic and research initiatives are inherently related, the means and resources associated with their development can be distinct. As a result, the recommendations are provided below in two sections related to Academic and Research Initiatives to differentiate the goals of the recommendations more clearly.

### *ACADEMIC INITIATIVES*

1. *Introductory course in QIS/QC*
   [Priority: High; Time to completion: Short]

As part of an initiative to increase student and faculty involvement in the academic growth of quantum computing at MSU, the QuTF recommends the development and continued support of an introductory course on the topic. This recommendation has already been met, as Dr. Yaroslav Koshka (ECE) and Dr. Mark Novotny (Physics) have co-taught a split-level Special Topics course ECE/PHY 4990-/6990 "Introduction to Quantum Computing" in Fall 2019, and plan to offer the course again in Spring 2022. There are plans to make the course permanent after the second offering, with the frequency of the offering dependent on enrollment.

Members of the QuTF have suggested that this course could be made part of existing undergraduate and graduate programs; however, this would be at the discretion of individual departments based on existing degree requirements and credit hour limitations. For future development of academic programs in QIS/QC, this course could be included as a required course (see Recommendations 2 and 3).

A potential challenge associated with a single-semester Introduction to Quantum Computing course is the need to cover certain topics at a satisfactory level of detail, which is dependent on the background of the students enrolled. The existing course is meant to serve as a general introduction to quantum computing, after which students would enroll in other courses based on their program of study; therefore, the topics covered would likely need to adapt to student needs.

2. *Cross-discipline QIS/QC minor or certificate*
   [Priority: Medium; Time to completion: Medium]

Following the approach of the Materials Certificate developed from the Materials Working Group (MWG), the QuTF recommends the development of a similar certificate in QIS/QC. As a QIS/QC Working Group already exists at MSU with some of the same members of the MWG, the QIS/QC Working Group, with the support of the Office of the Provost as needed, could move forward in defining associated courses that exist or that can/should be developed to meet the needs of the certificate. Such a program could serve as a pathway towards the development of full degree programs (either undergraduate or graduate) in QIS/QC (see Recommendation 3).

Moving a step beyond the certificate, the QuTF recommends the development of a minor in QIS/QC, to be housed in the Department of Physics. This would provide students the opportunity to take existing courses in Physics and ECE related to QIS/QC, above what would likely be required for a similar certificate, to augment their undergraduate or graduate degree program. A challenge for the minor would be the inclusion of prerequisite courses (such as computer science) while still maintaining the necessary number of hours to take courses directly associated with QIS/QC. It should be noted that specific courses and prerequisites for the minor and certificate should remain flexible (within reason) to allow for students from a variety of departments and backgrounds to enroll.

3. *Accelerated BS/MS 4+1 degree program*
   [Priority: High; Time to completion: Long]

The QuTF recommends the development of a cross-discipline BS/MS combined degree program. The BS would be in Physics, which would allow students to gain the basic knowledge required for more focused training in Quantum Computing within an Engineering program. Existing coursework is in place for students to earn a BS in Physics with a focus in QIS/QC, including:

- PH 2233, “Physics III”
- PH 3613, “Modern Physics”
- PH 4143, “Intermediate Laboratory”
- PH 4152, “Modern Physics Laboratory”
- PH 4413, “Thermal Physics”
- PH 4713, “Introduction to Quantum Mechanics”
- PH 4723, “Applications of Quantum Mechanics”
- PH 4813, “Introduction to Solid State Physics”

The MS degree would initially be awarded by the Department of Electrical and Computer Engineering, which already has faculty with expertise in quantum computing and related disciplines. Other departments, such as CSE within the Bagley College of Engineering, may later provide other such BS/MS combined degree programs. Towards that goal, three graduate-level Special Topics courses are under development in the Department of Electrical and Computer Engineering (ECE) that could serve as a basis for required coursework towards the MS degree. They are as follows:

- ECE 8990, Special Topics, “Quantum Machine Learning” (Y, Koshka, B. Tang, and J. Ball; to be offered in Fall 2022).
- ECE 8990, Special Topics, “Quantum Information Theory” (C.-H. Liu, Y. Koshka and J. Fowler; to be offered in Fall 2022).
- ECE 8990, Special Topics, “Quantum Game Theory” (S. Khan and Y. Koshka; under development).

The joint BS/MS program could be based either on the existing Accelerated Program (B.S./M.S. Combined Degree) in the College of Engineering, or the Computational Engineering program. Within this program, students can earn up to nine hours of graduate-level coursework during their final year of undergraduate studies, and they have the option to take graduate-level courses and earn both undergraduate credit and graduate credit simultaneously.

One of the primary challenges associated with this recommendation is the inherent cross-college nature of the proposed program, which will require discussion among administrators at various levels. Given the existing interdisciplinary collaborations in QIS/QC that exist at MSU, both in teaching and research, the QuTF is confident that although this coordination challenge is substantial, there is a clear precedent for success.

4. *Cluster hiring of QIS/QC faculty*
   [Priority: High; time to completion: Medium]

The QuTF strongly recommends focusing on cluster hiring among departments/colleges to build and enhance future academic and research programs that build on the trans-disciplinary nature of a QIS/QC degree program. Such an approach would allow for stronger collaboration between departments associated with QuTF by bringing in faculty with shared interests and/or expertise.

The QuTF suggests appointing an individual or group to explore the idea of hiring into experimental/hardware research targeting concepts such as quantum materials, micro/nano-electronics, qubits, and quantum interconnects, which, more than algorithms, may attract the lion's share of the QC funding in the next few decades. It was noted that members of the QuTF are predominantly computational scientists; therefore, the QuTF may not be fully qualified to answer that question. There are arguments against moving in this direction at MSU, but the QuTF is not confident that we have sufficient breadth of representation to make or not make such a recommendation. For example, maybe there have been new non-obviously relevant hires in experimental materials, chemistry, or physics in the past 3-5 years? To this end, the QuTF suggests investigating the feasibility of a follow-up Task Force or Working Group, possibly utilizing an existing group such as the Materials Working Group to identify which fields to pursue.

5. *QIS/QC outreach to MS middle/high school students*
   [Priority: Low; Time to completion: Medium]

Any academic programs at MSU would benefit from outreach that would generate interest in QIS/QC among middle and high school students within Mississippi. While existing resources and approaches using on-line content and live demonstrations should continue, the QuTF recommends additional outreach activities. For example, building on the American Physical Society graphic novel series "Spectra", lesson plans could be recorded and made available to encourage MS middle/high school students to "think quantum not classical". This initiative could include appropriate contests with MSU/quantum swag as prizes. Involvement of the College of Education and applicable external funding would be instrumental in developing and sustaining such a program.

Another initiative that would align this recommendation directly with programs at MSU is dual enrollment, which would allow high school students to earn credit towards courses associated with QIS/QC at MSU. For example, the Mississippi School for Math and Science (MSMS) currently offers dual-enrollment credit for classes such as Computer Science I and II (among others), which could help bring

students to MSU along a path towards a degree in QIS/QC. Developing and offering a course that introduces Quantum Computing concepts at a level relevant to high school and incoming undergraduate students would be beneficial in terms of recruitment.

The QuTF strongly agrees that addressing QIS/QC in the K-12 curriculum is critical to the future success of programs as MSU, and any opportunity should be taken to provide education on the question of "why quantum?" to younger students.

***RESEARCH INITIATIVES***

*6. Host MSU-wide information session / Develop inventory of researchers*
[Priority: High; Time to completion: Short]

In an effort to identify existing expertise in quantum information science and quantum computing at the local, regional, and national scale, the QuTF recommends developing an inventory of universities, research programs, and faculty with expertise in the disciplines of QIS/QC. Such an inventory would be valuable to new and existing researchers at MSU to help identify potential collaborators. Additionally, an inventory containing a listing of MSU faculty with expertise and experience in the fields of QIS/QC could serve as a catalyst for collaboration within the University by providing a means for Centers and Institutes to share/discuss research ideas with faculty and students.

Towards this end, an inventory of individuals associated with QIS/QC was generated in June 2019 by Allen Parish (with help from additional faculty), which includes details regarding the associated institution, funding amount, research productivity, collaborations, etc. This inventory is quite exhaustive; however, it is suggested that it be updated to reflect current involvement in the field of QIS/QC. The list is too large to be included in this document, but is available in digital form upon request.

In addition to this 2019 inventory, the list of academic institutions, corporations, and federally funded research and development centers (FFRDC) involved in the Quantum Economic Development Consortium (QED-C) can be used to define the major players in the disciplines of QIS/QC. This list can be viewed at the link below and is also provided in Appendix A (see Recommendation 7 for more information on the QED-C).

- QED-C | QED-C Members - QED-C (quantumconsortium.org)

In developing such an inventory, it would be worthwhile to give attention to disciplines that relate to or have arisen due to quantum computing. For example, the field of post-quantum cryptography may be of interest to centers such as NSPARC and the Center for Cyber Innovation (CCI). Post-quantum cryptography is a research topic directed towards developing cryptographic techniques that cannot be easily defeated by quantum computers. An area like this could generate useful collaboration between statistics, computer science, and quantum researchers, and could help guide MSU into a niche field within the broader context of quantum computing.

*7. Join the QED-C*
[Priority: High; Time to completion: Short]

The Quantum Economic Development Consortium (QED-C) is an organization focused on the development of a robust commercial quantum-based industry in the United States, and is comprised of a variety of

industry, academic, and federally funded stakeholders (see QED-C members page for full list). Per the QED-C website:

> "The Quantum Economic Development Consortium (QED-C) is a consortium of stakeholders that aims to enable and grow the U.S. quantum industry. QED-C was established with support from the National Institute of Standards and Technology (NIST) as part of the Federal strategy for advancing quantum information science and as called for by the National Quantum Initiative Act enacted in 2018."

Membership in the QED-C provides a number of benefits, including opportunities to:

- Attend invitation-only QED-C meetings with industry, government, and academic leaders.
- Participate in technical committees focused on use cases, enabling technologies, standards, and workforce.
- Participate in invitation-only workshops to define enabling technology priorities and roadmaps.
- Keep informed about Federal opportunities, priorities, and policies.
- Engage in collaborative QED-C-funded R&D.
- Access QED-C data, analysis, studies and more.
- Connect with academic researchers and students.
- Contribute to QED-C direction setting and governance.

Given the importance of the goals of the QED-C in future QIS/QC development at MSU, the QuTF recommends becoming a member of the Consortium. Membership requires the payment of annual dues, attendance of an annual meeting, and involvement in various activities.

In terms of specific and near-term benefits to joining the QED-C, membership could be highlighted at the NSPARC annual data summit, which will be held in October this year. Workforce will be a major theme for the summit, and the new directors of the Office of Workforce Development (OWD), Ryan Miller, and the chair of the State Workforce Investment Board (SWIB), Patrick Sullivan, will both be in attendance. They will play a large role in shaping the workforce-oriented breakout sessions, and this could be leveraged to highlight the QED-C and MSU's interests in QC in general. The possibility that SWIB or OWD funding could be available in some capacity at MSU is a strong motivation to move forward with this recommendation; therefore, at a high level, QIS/QC could be a session or two this year at the data summit to build interest, which could then serve as a springboard for a future regional conference hosted at MSU (see Recommendation 8).

8. *QIS/QC conference hosted at MSU*
   [Priority: High; Time to completion: Medium]

Given the importance of collaboration in developing strong research programs and enhancing the probability of funding, the QuTF recommends organizing a regional Quantum Computing conference at MSU. The conference would bring together local, regional, and national scholars to help foster collaborative proposal development and applied research objectives related to QIS/QC, and would help improve and solidify MSUs standing as a primary player in quantum computing research and teaching.

To help fund the conference, QuTF members suggested applying for the Established Program to Stimulate Competitive Research: Workshop Opportunities (EPS-WO) (nsf19588) | NSF – National Science Foundation. It should be noted that NSF EPSCoR funding requires the conference to be national in scope.

As this recommendation is deemed high priority, the QuTF recommended an action item of forming a working group to begin the process of planning and eventually organizing the conference. This working group would begin by determining the overall objective of the conference, both in terms of scientific content and potential benefits to MSU faculty, which would help define the scope/size of the conference. To maximize the impact of the conference, it was suggested that strategically selecting and inviting individuals interested in potential and/or current work in QIS/QC at MSU would be most efficient. Limiting the conference to ~25 invitees was considered appropriate in this approach, as discussions would be the primary purpose of the conference. The timing of the initial conference was also discussed, with summer 2022 and winter 2023 being proposed. This would place the recommendation in a medium time to completion, although given the time required for organization, the formation of the associated working group should occur quickly (summer 2021 if possible).

While the QuTF recognized the effort and commitment necessary to host such a conference, they also agreed that it would be a critical step in building MSUs reputation both regionally and nationally, eventually establishing MSU as a lead EPSCoR institution for quantum computing. Beyond the benefits of faculty having a chance to collaborate with other quantum computing researchers, other benefits associated with students interacting with invited speakers would include enhanced recruitment and potential employment opportunities for graduates.

9. *Student summer workshop*
   [Priority: Low; Time to completion: Medium]

A strong academic program in QIS/QC should include student research experiences to address the rapidly changing quantum industry and associated workforce requirements. As a result, the QuTF recommends developing a summer student learning program that can bring in students locally and regionally to foster collaborative research while providing hands-on training from existing QIS/QC experts. The program would focus on intensive coursework and/or guided research, and would give students exposure to and training in research applications and skills needed to be competitive in both industry and academics. This would further allow faculty to be directly involved in student learning outside of the classroom. Additionally, bringing in industry experts to lead the training would serve multiple benefits to both students (i.e., gain information on industry requirements and job opportunities) and industry representatives (i.e., recruiting future users of quantum resources, outreach opportunities).

Building on the recommendation of establishing a conference hosted at MSU (see Recommendation 8), the summer student program could coincide with the conference such that the workshop would culminate with attendance at the conference. This would give students the additional experience of interacting with other researchers, which would help foster future collaboration.

Tying this recommendation in to the outreach activities described in Recommendation 5, the student conference could include high-achieving high school students with interest in quantum computing. These students could be brought in as part of an internship or some other mechanism, giving them valuable research experience and training to launch them into a larger undergraduate program.

10. *Quantum computer*
    [Priority: High; Time to completion: Long]

Given MSU's current leadership and expertise in high performance computing, the QuTF recommended investigating the purchase of a quantum computer. It was recognized that the cost is high, though not

prohibitive, with an estimate of $10 million; therefore, one of the primary challenges associated with such a recommendation is determining an external funding mechanism. As the machine would be used for research purposes across multiple disciplines with applications in quantum computing, a larger collaborative group would need to work towards establishing the requirements and justification for the equipment. This would likely require the formation of a working group devoted to this particular recommendation, which would also need to formulate a cost-benefit analysis to illustrate the utility and advantages of such a purchase.

Regarding the cost-benefit idea, the QuTF established that the equipment purchase must be accompanied by the hiring of support staff to operate and maintain the equipment and associated facilities. Besides this, however, hiring of new faculty with expertise in quantum computing and related applications must be a priority. This approach of hiring researchers that would utilize the equipment would help justify the purchase, and conversely, the equipment could be used as an incentive to bring in new faculty (i.e., include computer time in a start-up package). An important caveat brought up by the QuTF was that rapid technology advances could make any particular quantum computer model quickly become obsolete, thereby decreasing the value and perceived benefit of purchasing a machine. It was noted, though, that once the infrastructure is in place, changing and updating the internal equipment would be a relatively small investment. Furthermore, this cost would likely be included as annual maintenance. As quantum computers are currently not available at academic institutions, moving forward with this recommendation would place MSU in a unique position, making it easier to find and justify funds to replace equipment in the future.

In terms of justification, MSU was recognized by the QuTF as being in a good position to move forward with this opportunity for a variety of reasons. First and foremost, any research applications involving quantum computing will likely require substantial classical computing resources for verification and testing purposes; therefore, the established high-performance computing infrastructure at MSU makes it a viable location. Second, as a quantum computer requires a specific environment to be housed (primary concerns are (1) cooling, (2) vibration reduction, (3) electromagnetic field noise reduction), current and/or proposed infrastructure at MSU could potentially house such a device. Depending on the type of device in question, the quantum computer could be housed in an existing location that already supports low-temperature equipment or in a space devoted to classical computer equipment. Either way, it was emphasized that a suitable location does not currently exist; however, existing locations could potentially be modified to support a quantum computer. Third, with the growth of academic programs in quantum computing along with research and outreach programs at MSU, obtaining a quantum computer would establish MSU as a solid player in the broader quantum community. It would also increase research applications and collaboration substantially be focusing interest regionally and nationally within the context of a computing center in a university setting.

## III. Summary and Paths Forward

MSU currently has a unique opportunity to move forward in developing academic and research programs in quantum information science and computing (QIS/QC). Given the current expertise, knowledge, and leadership that exists in terms of instruction and funded research in quantum computing, it is critical that we take advantage of this position and move forward quickly and aggressively to establish MSU as a center for quantum computing both regionally and nationally. It is the opinion of the QuTF that what the field of artificial intelligence (AI) is experiencing in this decade – in terms of both research and industry – will be the fate of QIS/QC in the coming decade. The unique window of opportunity will position us to be a

powerhouse in these fields and perhaps be a catalyst to realize the vision of MSU to become a top-50 research university. The fields impacted through advancements in QIS/QC span cybersecurity, material sciences, drug discovery, mission critical systems, environmental modeling, and many others.

To this end, the QuTF has provided 10 recommendations related to advancing QIS/QC at MSU that should be considered in the context of MSU's overall academic and research priorities. These recommendations, along with their suggested priority and time to completion, are as follows:

1. *Introductory course in QIS/QC* [Priority: High; Time to completion: Short]
2. *Cross-discipline QIS/QC minor or certificate* [Priority: Medium; Time to completion: Medium]
3. *Accelerated BS/MS 4+1 degree program* [Priority: High; Time to completion: Long]
4. *Cluster hiring of QIS/QC faculty* [Priority: High; time to completion: Medium]
5. *QIS/QC outreach to MS middle/high school students* [Priority: Low; Time to completion: Medium]
6. *Host MSU-wide information session / Develop inventory of researchers* [Priority: High; Time to completion: Short]
7. *Join the QED-C* [Priority: High; Time to completion: Short]
8. *QIS/QC conference hosted at MSU* [Priority: High; Time to completion: Medium]
9. *Student summer workshop* [Priority: Low; Time to completion: Medium]
10. *Quantum computer* [Priority: High; Time to completion: Long]

As the recommendations made by the QuTF have varying priorities and times to completion, individual specific working groups should be organized with the purpose of carrying out individual tasks. While QuTF members can certainly be involved and/or lead these groups, additional faculty members with expertise, experience, and interest in the associated task should be identified and recruited to increase the strength and breadth of the resulting programs. It should be noted that many of the recommendations are listed as high priority, mainly because of the need to develop QIS/QC programs early to establish MSU's reputation and standing in the discipline.

The benefits of establishing a strong presence and reputation in QIS/QC include increased student enrollment and additional research funding opportunities, among others. Together, the benefits would potentially lead to enhanced workforce development for MSU graduates in QIS/QC-related jobs. Furthermore, MSUs current research strengths in cybersecurity would greatly benefit from growth in quantum computing resources and training, making this a foundational investment with substantial short and long-term gains.

**Appendix A: Current Membership of the QED-C**

*Corporate*

| | | | |
|---|---|---|---|
| Aliro Technologies | Galois | OU Solutions | Scout Ventures |
| AlphaRail | GE Global Research | PayPal | Seeqc |
| Amazon Web Services | General Dynamics Mission Systems | Photodigm | Semicyber |
| Anametric | Google | Photon Spot | Sivananthan Laboratories |
| AOSense | Great Lakes Crystal Technologies | PQ Secure Technologies | Sky Quantum |
| Aperi Global | Honeywell | Physical Sciences Corp. | Speqtral Quantum Technology |
| AT&T | IBM | PsiQuantum | SRI International |
| Atom Computing | In-Q-Tel | Q-CTRL | Stable Laser Systems |
| Azimuth Corporation | Inside Quantum Technology | Q-Sensorix | StratConGlobal |
| Benchmark Electronics | Intel | QC Ware | StrategicQC |
| Bleximo | IonQ | QPRI | Sumitomo (SHI) Cryogenics of America |
| Boeing | JanisULT Research | Qrypt | Super.tech |
| Booz Allen Hamilton | JTEC Consulting | Quantum 1 Group | Terranet Ventures |
| Cisco | Keysight | Quantum Circuits | The Desner Group |
| Coherent | KMS Security | Quantum Computing Inc. | Thorlabs |
| ColdQuanta | L3Harris | Quantum Computing Report | TOPTICA Photonics |
| Corning | Lake Shore Cryotronics | Quantum Microwave | Toshiba America |
| Cosmic Microwave Technologies | Lockheed Martin | Quantum Opus | Vapor Cell Technologies |
| Cryomech | Marki Microwave | Quantum Semiconductor | Verizon Wireless |
| D-Wave Government Systems | Microsemi FTS | Quantum Xchange | Vescent Photonics |
| Deloitte Consulting | Microsoft | Qubitekk | Wells Fargo |
| Entanglement Institute | Montana Instruments | QuEra Computing | XMA Corporation |
| Equal1.Labs | Northrop Grumman | Qunnect | Xofia |
| FLIR Systems | Novum Industria | Raytheon-BBN Technologies | Young Basile Hanlon & MacFarlane |
| FormFactor | NuCrypt | Rigetti Computing | Zapata Computing |
| Freedom Photonics | ODE L3C | Rydberg Technologies | Zettaflops |
| Frequency Electronics | OEwaves | Safe Quantum | Zyvex Labs |

*Academic*

| | | | |
|---|---|---|---|
| Clark Atlanta University | New York University | SUNY Polytechnic Institute | University of Nevada – Reno |
| George Mason University | North Carolina State University | Texas A&M | University of Oklahoma |
| Georgia Institute of Technology | Northeastern University | University of Arizona | University of Rochester |
| Hampton University | Northwestern University | University of California – Los Angeles | University of Washington |
| Harrisburg University of Science and Technology | Pittsburgh Quantum Institute | University of California – Santa Barbara | University of Wisconsin |
| Howard University | Purdue University | University of Chicago/Chicago Quantum Exchange | Virginia Tech |
| Indiana University | Rochester Institute of Technology | University of Colorado | |
| Lehigh University | Southern A&M University | University of Illinois | |
| Morgan State University | Southern Methodist University | University of Maryland | |

*Federally Funded R&D Centers*

| | | | |
|---|---|---|---|
| Brookhaven National Laboratory | Lawrence Livermore National Laboratory | MITRE Corporation | Sandia National Laboratories |
| Fermi National Accelerator Laboratory | Los Alamos National Laboratory | Oak Ridge National Laboratory | SLAC |
| Lawrence Berkeley National Laboratory | | | |

*Other*

| | | | |
|---|---|---|---|
| American Physical Society | MinneQuantum | SEMI | US Advanced Computing Infrastructure |
| Electronic Power Board (EPB) | Optical Society of America | SPIE | Washington State Department of Commerce |
| EMW Consulting, LLC | Quantum Computing Report | Universities Space Research Association | |