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The 2022 CHIPS and Science Act will accelerate research and innovation in and develop workforce for Quantum Information Science

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On August 9, 2022, President Joe Biden signed into law the CHIPS and Science Act, which had garnered bipartisan support. The CHIPS and Science Act authorizes the largest publicly funded R&D program in the country's history as well as implements programs under the CHIPS for America ACT of 2021. The five-year funding includes $54.2 billion for the CHIPS act 2022, $24 billion for investment tax credit and $169.9 billion for Science (Research and Innovation). In section 10387, which lists challenges and focus areas, Quantum information science and technology has been identified as a key technology focus area. This marks a significant milestone for and gives a significant boost to quantum information science after nearly forty years of advanced research at universities, and cutting-edge technology development in the industry since the advent of the BB84 scheme for secure communication, and quantum algorithms for computation pioneered by Deutsch and Shor. It is an achievement of the entire quantum community.

According to the White House briefing, the intent of the CHIPS and Science Act is to lower costs, create jobs, strengthen supply chains, and counter China. America invented the semiconductor, but today produces about 10 percent of the world's supply—and none of the most advanced chips. In comparison east Asia contributes to 75 percent of global production. Another objective of the new law is to ensure the future is made in all of America. It directs the Department of Commerce to create geographically distributed "regional technology and innovation hubs" in areas that are not leading technology centers.

The CHIPS part of the CHIPS and Science Act provides $54.2 billion for American semiconductor research, development, manufacturing, and workforce development. This includes $39 billion in manufacturing incentives, $13.2 billion in R&D and workforce development, $500 million to provide for international information communications technology security and semiconductor supply chain activities and $1.5 billion for the Public Wireless Supply Chain Innovation Fund. It also provides 25 percent investment tax credit for capital expenses for manufacturing of semiconductors and related equipment. To ensure that the manufacturing incentives advance U.S. technology leadership and supply chain security, the Act would require recipients of Federal financial assistance to join an agreement prohibiting certain material expansions of semiconductor manufacturing in the People's Republic of China or in other countries of concern. The restrictions would apply for ten years. CHIPS is an acronym of a cleverly crafted name "Creating Helpful Incentives to Produce Semiconductors".

Funding for Quantum Information Science is included in the "Science" part of the CHIPS and Science Act, which is covered under division B. Those with a knack for numbers will get a kick out of the word count statistics in the H.R. 4346 bill which became law. The word "quantum" comes in second at 126 counts behind "data" at 282 counts but is used more than "cyber" at 106, "artificial intelligence" and "machine learning" at 57, "chip" at 24 and "laser" at 14. Within the realm of quantum, "network" is cited 35 times and "computing" is cited 12 times. What is amusing is that even the words "entanglement" and "hyper-entangled state" appear in

the bill four times. Personally, I (SB) could not dream "hyper-entangled state" being included in a law when I was studying quantum mechanics many years ago. How times have changed!

The funding for quantum research is included in division B of the CHIPS and Science Act under DOE, NIST and NSF.

Quantum Information Science funding in DOE:

The Basic energy sciences program (sec. 10102) calls for recapitalization of the Nanoscale Science Research Centers to include quantum information science.

Under Advanced Scientific Computing Research Program (Sec. 10104), subsection (b) authorizes a research, development, and demonstration program to accelerate innovation to support quantum network infrastructure and authorizes $100 million per year for FY 2023 through FY 2027 for this program. It also directs the Secretary to establish a Quantum User Expansion for Science and Technology program (QUEST) to encourage and facilitate access to the United States quantum computing hardware and clouds for research purposes. The subsection authorizes $165.8 million for five years ending in FY2027 for the QUEST program.

The objective of the Advanced Scientific Computing Research Program is to establish a program to achieve computing systems well beyond the current state of the art. This shall entail foundational research programs in many areas including quantum computing, quantum accelerators and distributed high-performance computing. Further objective is to support computational science graduate fellowship program to facilitate collaboration between graduate students and the national labs in all areas of computational science including quantum computing.

In the law, quantum network infrastructure means any facility, expertise, or capability that is necessary to enable the development and deployment of scalable and diverse quantum network technologies. Sec 403 covers the Department of Energy quantum network infrastructure research and development program. The law instructs to carry out a research, development, and demonstration program to accelerate innovation in quantum network infrastructure in order to

(1) facilitate the advancement of distributed computing systems through the internet and intranet.

(2) improve the precision of measurements of phenomena and physical imaging technologies,

(3) develop secure national quantum communications technologies and strategies

(4) demonstrate quantum networking utilizing the Department of Energy's Energy Sciences Network User Facility; and

(5) advance the relevant domestic supply chains, manufacturing capabilities, and associated simulations or modeling capabilities.

In carrying out the above-mentioned objectives, the law requires

(1) Coordination among DOE and NSF, National Science and Technology Council, and Subcommittee on the Economic and Security Implications of quantum science
(2) Conducting cooperative research with industry, national laboratories and universities to develop new quantum infrastructure methods and technologies, including –

a. quantum-limited detectors, ultra-low loss optical channels, space-to-ground connections, and classical networking and cybersecurity protocols;
b. entanglement and hyper-entangled state sources and transmission, control, and measurement of quantum states;
c. quantum interconnects that allow short range local connections between quantum processors;
d. transducers for quantum sources and signals between optical wavelength regimes, including telecommunications regimes and quantum computer-relevant domains, including microwaves;
e. development of quantum memory buffers and small-scale quantum computers that are compatible with photon-based quantum bits in the optical or telecommunications wavelengths;
f. long-range entanglement distribution, including allowing entanglement-based protocols between small- and large-scale quantum processors, at the terrestrial and space-based level using quantum repeaters and optical or laser communications;
g. quantum routers, multiplexers, repeaters, and related technologies necessary to create secure long-distance quantum communication; and
h. integration of systems across the quantum technology stack into traditional computing networks, including the development of remote controlled, high-performance, and reliable implementations of key quantum network components by leveraging the expertise, infrastructure and supplemental investments at the National Laboratories in the Energy Sciences Network User Facility;

(3) Engagement with organizations such as the Quantum Economic Development Consortium (QED-C) to help facilitate the development of a quantum supply chain for quantum network technologies and components;

(4) Conducting basic research in advanced scientific computing, particle and nuclear physics, and material science to enhance the understanding, prediction, and manipulation of materials, processes, and physical phenomena relevant to quantum network infrastructure;

(5) Development of experimental tools and testbeds in collaboration with the Energy Sciences Network User Facility necessary to support cross-cutting fundamental research and development activities with diverse stakeholders from industry, National Laboratories, and institutions of higher education; and

(6) Consideration of quantum network infrastructure applications that span the Department of Energy's missions in energy, environment, and national security.

Funding authorized to be appropriated to carry out the activities under this section is $100 million for each of fiscal years 2023 through 2027.

Department of Energy Quantum User Expansion for Science and Technology Program (sec. 404):

The Department of Energy has been allocated $165.8 million over the next five years to establish the Quantum User Expansion for Science and Technology (QUEST) program. The program is intended to expand access to quantum computing resources among researchers based in the United States. Participant researchers will be selected through competitive, merit-based

processes and provided access to United States quantum computing hardware and infrastructure. By facilitating the use of U.S. quantum computing resources, the program is intended to encourage quantum research, train the quantum computing workforce, and develop the infrastructure and capabilities necessary to support quantum computing research in the United States.

Quantum Information Science funding in NIST:

Section 10230 directs the director of NIST to carry out a program of measurement research for advanced communication technologies. Research area may include optical and quantum communications technologies.

Quantum Information Science funding in NSF:

The Federal cyber scholarship-for-service program (Sec. 10316) clarifies that cybersecurity-related aspects of artificial intelligence, quantum computing, and other fields are within the scope of the NSF CyberCorps Scholarship-for-Service program.

Under Subtitle G, section 10381 the law establishes the Directorate for Technology, Innovation, and Partnerships within the National Science Foundation to advance research and development, technology development, and related solutions to address United States societal, national, and geostrategic challenges, for the benefit of all Americans. The Director shall identify, and annually review ten key technology focus areas including Quantum information science and technology.

Funding for Quantum networking and communications is included in Title VI—Miscellaneous Science and Technology Provisions, subtitle G – Quantum networking and communications, Sec. 10661. Sec. 10661 (Quantum Networking and Communications) requires the Subcommittee on Quantum Information Science of the National Science and Technology Council to create a report and Federal strategy for quantum networking and communications research. The provision also directs the National Institute of Standards and Technology to conduct research and standardization activities to support quantum networking and communications technologies. It directs the National Science Foundation ("NSF") to conduct quantum information science education and workforce development activities, including establishment of a quantum education pilot program to promote quantum information science workforce development across the nation. The Director of the NSF also must engage the National Academies for a study on the educational challenges associated with creating a diverse, flexible, and sustainable quantum workforce.

Report on Quantum networking and communications: By January 1, 2026, the Quantum Networking Working Group within the Subcommittee on Quantum Information Science of the National Science and Technology Council, in coordination with the Subcommittee on the Economic and Security Implications of Quantum Information Science, shall submit to the appropriate committees of Congress a report detailing a plan for the advancement of quantum networking and communications technology in the United States, building on the report entitled A Strategic Vision for America's Quantum Networks and A Coordinated Approach for Quantum Networking Research.

The report should include (A) an update to the report entitled "Coordinated approach to quantum networking research report" focusing on framework for interagency collaboration, (B) a plan for Federal Government partnership with the private sector and interagency collaboration regarding engagement in international standards for quantum networking and communications technology, (C) a proposal for the protection of national security interests relating to the advancement of quantum networking and communications technology, (D) an assessment of the relative position of the United States with respect to other countries in the global race to develop, demonstrate, and utilize quantum networking and communications technology, (E) recommendations to Congress for legislative action relating to the matters considered under subparagraphs (A) - (D), and (F) all other matters the Quantum Network Working Group will consider necessary to advance the security of communications and network infrastructure, to remain at the forefront of scientific discovery in the quantum information science, and to transition quantum related research into the emerging quantum technology economy.

Under the heading of "Quantum networking and communications research and standardization", the law instructs amendment of section 201 of the National Quantum Initiative Act (15 U.S.C. 8831) to include:

(3) shall carry out research to facilitate the development and standardization of quantum cryptography and post-quantum classical cryptography;

(4) shall carry out research to facilitate the development and standardization of quantum networking, communications, and sensing technologies and applications; and

(5) for quantum technologies determined by the Director of the National Institute of Standards and Technology to be at a readiness level sufficient for standardization, shall provide technical review and assistance to such other Federal agencies as the Director considers appropriate for the developments of quantum networking infrastructure standards.

To carry out paragraphs (3) through (5) of subsection (a) of section 201 of the National Quantum Initiative Act, $15 million is authorized for each of fiscal years 2023 through 2027.

Workforce development:

Quantum Information Science Workforce Evaluation and Acceleration:

NSF will conduct a study on the quantum information science (QIS) workforce. This study will address a wide range of topics pertaining to the quantum workforce and make recommendations for developing the QIS workforce based on its findings. Some key goals of the study will be: (a) to identify the skills and qualifications needed by QIS workers; (b) to characterize the size and composition of the QIS workforce now and in the future; (c) to assess the academic coursework and interdisciplinary degree programs necessary to prepare students for QIS careers; and (d) to evaluate how well current education and skills training meets the needs of the QIS workforce and identify areas for improvement – this evaluation will investigate QIS readiness at all levels of education: K-12 students' access to foundational curricula; K-12 teachers' access to relevant course material and professional development opportunities; higher education curricula, lab training, and degree programs; and professional certifications or other avenues for professionals to make mid-career transitions into the QIS workforce.

Incorporating Quantum Information Science and Engineering (QISE) into STEM Curriculum:

NSF will work to incorporate QISE into STEM curricula at all levels of education. This initiative will aim at developing age-appropriate materials for students at all levels of education, from K-12 to higher ed, including community colleges. Further, this initiative will work to ensure that students from groups that are underserved or historically underrepresented in STEM have access to these new QISE curricula. This project will draw upon the findings and recommendations outlined in the NSF study of the QIS workforce (introduced in the previous section).

Quantum Education Pilot Program:

NSF has been allocated $32M over the next four years to establish the "Next Generation Quantum Leaders Pilot Program." The goal of this program is to educate students and train teachers at the K-12 level in the core principles of quantum information science (QIS). To pursue this goal, NSF will offer competitive, merit-based grants to institutions of higher education, nonprofits, and other such organizations; these awardees will then partner with K-12 schools. The NSF grant funding will be used to: develop and implement QIS curricula which are appropriate to the K-12 grade levels; incorporate QIS into the broader STEM curriculum; offer opportunities for students to explore QIS higher education programs and career paths; and develop professional development and training programs in QIS for teachers. The legislation emphasizes that this pilot program should be implemented equitably, so that the education and training opportunities it offers are widely accessible to students from many geographic areas and backgrounds, including those from groups historically underrepresented in STEM fields. Four years after the implementation of this pilot program, NSF will produce a report which (a) assesses the program's efficacy in developing quantum education and training, using feedback from its participants; and (b) assuming the success of the program, develops a plan to expand the program and integrate its methods into other existing programs.