SAND2017-3550R

Quantum Testbeds Stakeholder Workshop (QTSW) Report

Purpose of the Meeting and Agenda Overview

Quantum computing (QC) is a promising early-stage technology with the potential to provide scientific computing capabilities far beyond what is possible with even an Exascale computer in specific problems of relevance to the Office of Science. These include (but are not limited to) materials modeling, molecular dynamics, and quantum chromodynamics. However, commercial QC systems are not yet available and the technical maturity of current QC hardware, software, algorithms, and systems integration is woefully incomplete. Thus, there is a significant opportunity for DOE to define the technology building blocks, and solve the system integration issues to enable a revolutionary tool. Once realized, QC will have world changing impact on economic competitiveness, the scientific enterprise, and citizen well-being.

Prior to this workshop, DOE / Office of Advanced Scientific Computing Research (ASCR) hosted a workshop in 2015 to explore QC scientific applications. The goal of that workshop was to assess the viability of QC technologies to meet the computational requirements in support of DOE's science and energy mission and to identify the potential impact of these technologies. That ASCR report commented that research into QC technologies was making rapid progress and that it is important for the ASCR Program to understand the utilization of these new technologies for DOE-relevant applications and their impact on conventional computing systems. They also noted that scientific application development will make significant advances only when QC systems are available, even at the few-qubit level.

ASCR sponsored a second workshop, the QTSW, in February of 2017 that brought together a diverse group of stakeholders from academia, industry, government, and DOE laboratories. The purpose of the QTSW was to identify opportunities and challenges in establishing a collaborative research facility to advance QC hardware and software systems to eventually enable science investigations. As envisioned, the testbed would provide a broad and rapidly growing research community with access to early stage QC devices to advance QC for science applications, lead to new insights as to how to design the next generation of hardware and software, and lower the barriers to entry into the field. The testbed will be unique in the world – there are no other facilities that offer the opportunity for hands-on, fully-transparent access to operational qubit systems. Additional benefits include, but are not limited to, bridging institutional and disciplinary boundaries, training a new workforce, educating the public, and supporting the development of commercial tools.

The recent workshop was structured to provide a forum for all stakeholders to provide their thoughts and guidance in helping define the overall goals and objectives of a testbed program and how that program would be synergistic with other nascent QC efforts in the US and worldwide. Stakeholders identified their individual capabilities and interests in QC hardware and software; shared best practices for management of collaborative research facilities, including topics such as workforce training and building strong relationships with the research community; and reviewed specified technologies that will be important for the success of a testbed facility with the overall goal of advancing QC for scientific applications in the next five years. The workshop overview provided below is expanded upon later in this report.

After an introduction by the program manager on the goals for the meeting, four plenary technical talks provided a status update on key elements of the testbed design. Chris Monroe and Will Oliver, focusing on trapped ion and superconducting systems respectively, reviewed the

status of each of these systems and discussed the relative advantages and disadvantages of each with regards to fidelity, interconnectivity, scaling, and reproducibility. Jarrod McClean offered a number of possible near term applications for QC systems that would begin to demonstrate the utility of QC systems to solve currently intractable problems in material science. Finally, Robin Blume-Kohout reviewed the current methods for evaluating the efficacy of quantum hardware systems to ensure they are performing as desired and guidance on what to fix if they are not working as hoped. The balance of the first day included presentations by the DOE laboratories wherein they identified their individual capabilities and interests in QC and its use for science applications.

On the second day, programmatic issues and technical challenges were the focus. To gather community input on the programmatic topics of testbed structure and operation, three breakout sessions were organized consisting of expert panels and leader guided discussion. Those sessions focused on best practices for the management of a testbed facility with lessons learned from other programs; the role the testbed will play in staffing and workforce development; and how to develop a vibrant user community. Recognizing the value of a vigorous codesign process to the success of the testbed, the attendees then returned to a common session to discuss lessons learned from prior ASCR codesign efforts and how those lessons apply to the relatively immature area of QC. The balance of the second day was an extensive set of breakouts focused on the hardware and software technologies, including qubit technologies, architectures, verification and validation of system performance, interconnects, and software interface layers.

The final day started with a summary discussion of the breakout session from the previous day and then moved quickly to an industry panel discussion. The panel shared their guidance on the role that an ASCR Quantum Testbed could serve in nucleating a community of practitioners, developing hardware and software tools, and identifying QC-worthy problems. Breakout sessions then explored the roles of industry and government in shaping a coordinated national QC vision, and the challenges in constructing a functional QC by combining the work of many subfields. After a review of the industry breakout discussion and comments by the federal program manager, the workshop concluded.