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Quantum Testbed Stakeholder Workshop (QTSW)

Working title for this section: Building the Future QC Community with a Testbed

Breakout Session: Best practices for management of and access to a quantum computing testbed

Now and throughout their history, the DOE and the Office of Science have sponsored a wide range of scientific facilities, each with its own unique culture and governance model that fosters an experience that enables user scientific advances. As such, there are many examples of organizational structures and cultures that provide a first-class user experience and also examples where the actions of the management team did not result in the desired outcomes. This section explores some of these examples, and highlights the guidance offered by the workshop attendees at this breakout session.

Given the importance of the testbed access model, prior to the QTSW, whitepapers were invited that addressed the following elements of a user model:

- Construction, deployment, and user-access to a quantum computing testbed (based on existing qubit technology)
- System and software architecture (programming interfaces, simulation and emulation capabilities, etc.)
- Scaling with respect to number of qubits in each prototype computational device, and the number of prototype devices
- Outreach activities to develop and foster a user community, including STEM education and public outreach in addition to outreach within the research community
- Ensuring scientific excellence, e.g. advisory board structure, proposal mechanism

In addition to the whitepapers, five managers with experience operating DOE and NSF user access facilities were asked to provide their guidance and help lead a breakout discussion. Panel members were from National Science Foundation (NSF) user facilities and from DOE / Basic Energy Sciences (BES) Nanoscience Centers—the Center for Integrated Nanomaterials, the Argonne Leadership Computing Facility, and the Combustion Research Facility(CRF). Collectively, the experiences of these centers yielded the following key points:

1. The process of defining metrics and program goals must include the needs of the user community. While this may seem obvious, there were multiple examples from the panel discussion where this point was not always observed.
2. A strong advisory committee representing the entire user community is important to guide investments and directions. This seemed especially important to the panel given the relative immaturity of QC technology. In those cases, past experiences strongly suggest that an agile and flexible management team that develops a roadmap, and works closely with all relevant stakeholders, is better positioned for long term success.
3. It takes time to build a user community for a facility or testbed. The importance of a physical location where people can visit in person and interact in multiple ways is important to codesign. If the center had only virtual access, then the time required to build the user community would likely be increased.
4. Moreover, the management/access model must be flexible and change as the technology and testbed matures. With the accelerated cycles of learning expected in the early

development of the testbed, modifications would be expected on a 6-month cycle, not a multiyear cycle.

In addition to the summary points above, the whitepapers and additional interactions at the workshop provided the following guidance:

Lessons learned from experiences at other user facilities. The NSF representative shared an example of a prior NSF center focused on development of microwave interferometer technology that he believed was analogous to the challenges faced by the Quantum Testbed program. For both programs, the focus involves relatively immature technology on the cutting edge of the possible and an unclear system integration path to blend that technology into a functional system. The example program was successful because: the community identified the most challenging engineering issues and took ownership of the final objective; the goals and metrics evolved as the technology matured; the program was led by agile program leaders who were also practitioners in the field; and importantly, the ambition and goals were matched by the corresponding required budget. Another facility manager offered a negative counter-example as they described a facility that developed a new capability only to have very few users. In retrospect, it is believed this occurred because the user base was not surveyed to uncover the community needs as a prerequisite to facility planning.

The role of the testbed in bridging the gap between the academic and industry communities. In general, there was consensus that the national laboratories can serve as a bridge between these communities because they offer a professional staff that can be tasked with transitioning academic advances into initial practice. When the path of maturing qubit assemblies and the interface layers between hardware and software is ill-defined, there is a need for an environment where accelerated cycles of learning or failing fast is rewarded without possible repercussions on careers. This is a common mode for national laboratories to provide value at the early stages of technology maturation. Another observation about the testbed is that it lowers the barriers for entry into the field by academics and industry by providing a way for them to prove out (or not) their technology building block by injecting it into an operational system. New users do not require a fully functioning system of their own to test out their concept. Others noted that there is a natural tension in the testbed concept between hardware development and actual usage of the testbed for scientific simulations. While both are important, the consensus was to incorporate new technology into the testbed when it was available but that the primary goal should be making qubit systems available to users. There is much to be learned about how ensembles of qubits work that will help inform the next generation of hardware. Finally, it was noted in this session and others, that the testbed will enable training for students who will then launch careers in industry.

The impact and importance of interface standards. There was a diversity of thought about the importance of, and priority for, setting interface standards. Standards can help broaden the user base by clarifying how new technology building blocks can be integrated into an operating QC system, thereby leading to a more engaged user community and driving innovation in all the stakeholder communities. However, if not broadly agreed to by the user community, standards can impede progress by unduly constraining the solution space. Thus, helping to recognize when a standard may be required and then helping to foster a working group to gather user community input could be one of the roles for a quantum testbed advisory panel. Additionally, there was agreement that standards need to be flexible enough to evolve rapidly as the hardware /software stack matures. A secondary benefit of the identification of standards could be the development of a language to describe QC performance: Currently, there is no standard or even rough agreement on what constitutes a QC, how to compare one QC to another, or how to describe the performance of individual elements with the QC system. As the hardware and interface software layers (stack) become available as part of the testbed program, the communities' lexicon will also evolve to be able to compare the performance system elements to optimize the QC for the problem at hand.

Metrics for success. The panel members described what their centers use for metrics of success. In many cases, metrics were the number of publications and number of users served. These are reasonable metrics for an established facility mostly stocked with mature tools but may not be the best metrics for a quantum testbed where the technology is rapidly evolving and the goal is to accelerate system-integration innovations. Pulling from the NSF example, technical performance metrics may be the most appropriate in the first few years. It was noted that there is an inherent tension between maintaining the testbed strictly for user access and the continual churning of hardware and software that is at the heart of codesign. One suggestion for the early stages of the testbed was to run in a campaign mode, alternating between cycles of operation and engineering improvement. This suggestion was supported by the success of an NSF center that operated in technology operation / improvement cycles until a reasonably stable prototype was available to serve as a secondary test bed.

Role of the Advisory Panel (AP). From both the panel and room discussion, there was good agreement on the role that an advisory panel should play. The advisory panel should counsel the testbed management on success metrics, oversee progress, and serve a significant role in growing the user base by collegial interactions and their own potential involvement in the testbed program. One of the examples from the NSF center highlighted that the advisory panel members should be leading experts in the field and help set the near-term and long-term objectives for the testbed; these functions are critical to maintaining user engagement, utilizing the best contributors from across the DOE complex, and maintaining the support of the broader community. The AP should also help evaluate and prioritize proposals for user access in the context of the overall roadmap but only when the requests for access begins to exceed the ability of the testbed to accommodate them. Frequently repeated advice was to not get bogged down in process. Finally, because it is expected that the early stages of the QC will be capital-intensive, prioritizing available capital resources and leveraging other programs such as hardware / software programs in the academic, industry and national labs will be critical.

The balance between onsite and virtual access to the testbed. Transparency of the system design and full access to the controls of the QC were deemed critical to rapid progress. These principles were balanced by the recognition that full access carries risk to the operation of the hardware. These two views can be mitigated by a graded approach to access that will evolve with time. While the first testbeds are being assembled, access could be via onsite visits or email discussions with the professional team that is in daily contact with the hardware / software stack. It was also recognized that as the system matures or more than one testbed is developed, there would be significant advantages to opening up the access to one of the testbeds via a virtual access portal. The IBM experience offers several lessons—the virtual access portal generated a large number of users, valuable metadata was generated on how the system was actually used, and an engaged public response. However, it was noted that a DOE user testbed would operate with greater transparency and with the ability to control more qubit parameters. The IBM web interface was also achieved at a significant overhead cost that in the early stages of the testbed may not be the best use of resources. Finally, given the world-wide government investment in QC technologies (which in several cases is larger than the US investment,) the QC testbed should both expect and actively encourage engagement with the international community.