DR. TRAVIS HUMBLE

Dr. Travis Humble is a Distinguished Scientist at Oak Ridge National Laboratory and Director of the lab's Quantum Computing Institute. He received his doctorate in theoretical chemistry from the University of Oregon before coming to ORNL in 2005. Dr. Humble leads the Quantum Computing Team in the Quantum Information Science Group. He is also an associate professor with the Bredesen Center for Interdisciplinary Research and Graduate Education at the University of Tennessee, Editor-in-Chief for ACM Transactions on Quantum Computing, and an Associate Editor for the Quantum Information Processing journal. As director of the QCI, Dr. Humble oversees research and development of Quantum Computing technologies. At the intersection of computing, physics, and information, his research focuses on the design, development, and benchmarking of new Quantum Computing platforms. These revolutionary new approaches to familiar computational problems include reducing algorithmic complexity, reducing the computational resource requirements like power and communication, and increasing the problem sizes to be tackled by state-of-the-art scientific applications.

The Beginnings of a Quantum World

The new paradigm of quantum information processing promises remarkable advances that may soon surpass conventional limitations in computing, communication, sensing and many other technologies. This includes methods for secure communication, energy-efficient computing, and high-resolution sensing. But this is only the beginning of how quantum information will change our world. Like the digital revolution of the past 70 years, quantum information is expected to transform our global community – but where will the quantum revolution lead us?

The technical and social disruptions expected from quantum information are unprecedented but not completely unknown. The original vision was to highlight the paradoxical nature of non-local correlations that define quantum mechanics. This paradox is illustrated by the case of a pair of dice that always roll to the same random value. This is highly suspicious within a classical context but exactly the type of entanglement observed when characterizing quantum particles. Reconciliation of this counter-intuitive quantum behavior evolved into conceptual experiments that soon came to define innovative applications to the theory of information. A leading example is the proposal by Nobel Laureate Richard Feynman to harness the quantum mechanics of individual atoms and electrons to simulate the dynamics of physical systems, a concept later known as Quantum Computing.

After decades of refinement, we are beginning to realize that the early visions of quantum information actually define a much more radical change. This is clearly illustrated by the discovery that Quantum Computing would enable new methods for solving important problems long thought to be near-impossible. For example, factoring large numbers had been considered too difficult to solve with conventional computers and it was widely adopted to secure public key encryption methods such as HTTPS. But the discovery of an efficient quantum algorithm for factoring changed this perspective by showing that a quantum computer enables an exponential speedup in the time needed to solve this problem. The radical change to the original computational assumptions now challenges the security of many secure communication networks, even though such a computer is not yet available. Similar advantages have been discovered for a number of other challenging problems, including unstructured search, machine learning, physical simulation, predictive modeling, logistics, and scientific discovery.

This potential for disruptive change recently made a leap forward with the demonstration of quantum computational supremacy. Quantum computational supremacy marks an achievement in which control over quantum physical systems known as qubits

enables a computation that cannot be matched by conventional computing resources. The first example of quantum computational supremacy was demonstrated recently using a 53-qubit processor which performed a diagnostic test to confirm the chip was working as expected. This diagnostic computation was compared to the expected results calculated using the world's fastest supercomputer found at the US Department of Energy's Oak Ridge National Laboratory. Through a series of increasingly more difficult tests, the comparison concluded that the quantum processor performed the complete diagnostic test in approximately 200 seconds, whereas the conventional computer simulation would ultimately require approximately 10,000 years. Alongside the remarkable difference in time-to-solution, there was a corresponding difference in energy consumption – the quantum computer was approximately 10,000,000 times more energy efficient as compared to the HPC system.

The first demonstration of quantum computational supremacy as well as many other early advances offer a glimpse into the dramatic changes that await a “quantum world”. These advances are now driving forward a global effort to harness the power of quantum information, and research laboratories across the world have begun to test and evaluate practical applications, with a few efforts testing first-generation products. Yet the technological race for a competitive edge has only just begun to build the workforce and infrastructure required for transformational change, where new skills and understanding are necessary to integrate quantum technologies into our existing information paradigms. Industry, governments, and professional societies are supporting efforts to train and educate quantum scientists and engineers while incentivizing the development of new ideas and products.

We are only seeing the beginnings of a quantum world that will herald big changes in the future for computing and other forms of information processing. As we continue to pass more technological milestones, we will integrate these concepts and drive forward to the competitive advantages offered by quantum information.