Quantum Technology & NASA

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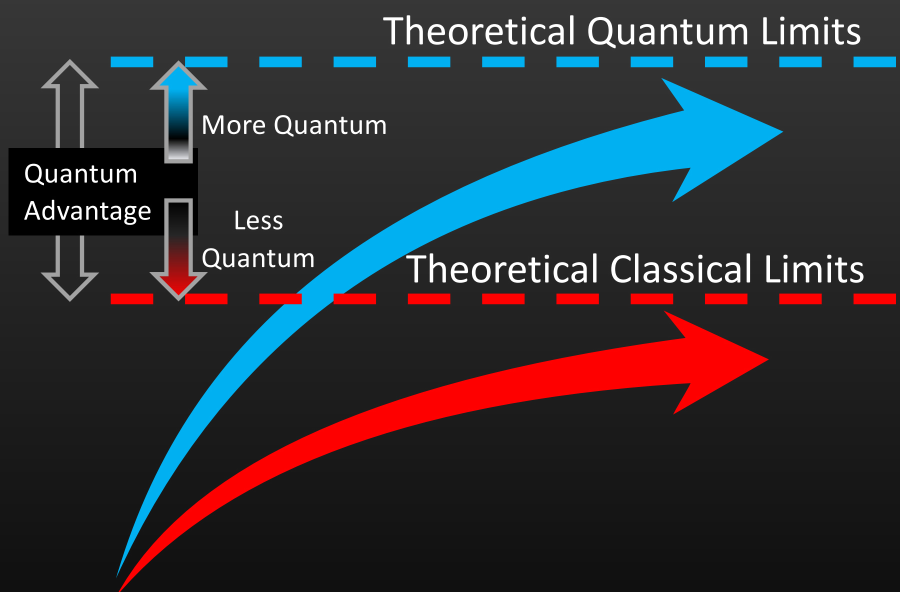
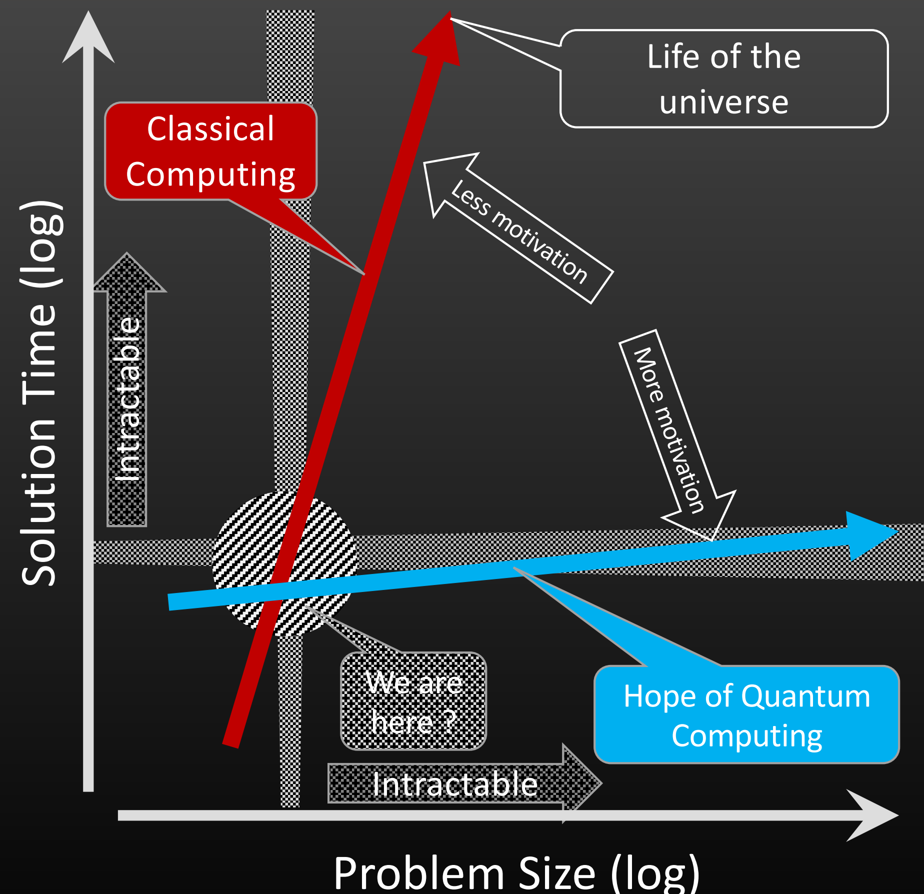
Background

- Much of the promise and impact of quantum science & technology (QST) is about the collection, generation, processing, and communication of information
- Take a holistic view of QST that merges quantum physics and information science to connect to applications
- QST is not a replacement for classical technology
- Each is likely to make the other better and together lead to beyond classical capabilities in select applications
- The worldwide heightened interest in QST stems from the advances made during 20+ years of basic research

The Promise

- A gap not bridged by classical technology





Essentials of the QIP model

- Quantum information processing (QIP) is probabilistic
  - Quantum mechanics is inherently probabilistic
- Processing steps can be arranged (algorithms/circuits) so that certain probabilities are amplified and others are depressed (zeroed)
  - Picture interference fringes from a double slit light (photon) experiment
- Information is exponential in the size of the system (superposition)
- Entanglement provides access to the exponential information space
- Superposition and entanglement are intrinsic to realizing beyond classical advantages

Challenges

- Keeping quantum elements quantum
  - Materials, fabrication
  - Precision classical control of the quantum building blocks
  - Control of the environment in which the blocks operate
- Keeping the quantum system quantum
  - Integrated quantum systems
  - Scale-up of control
- Fault-tolerance
- Modularity
- Algorithms, software, and applications

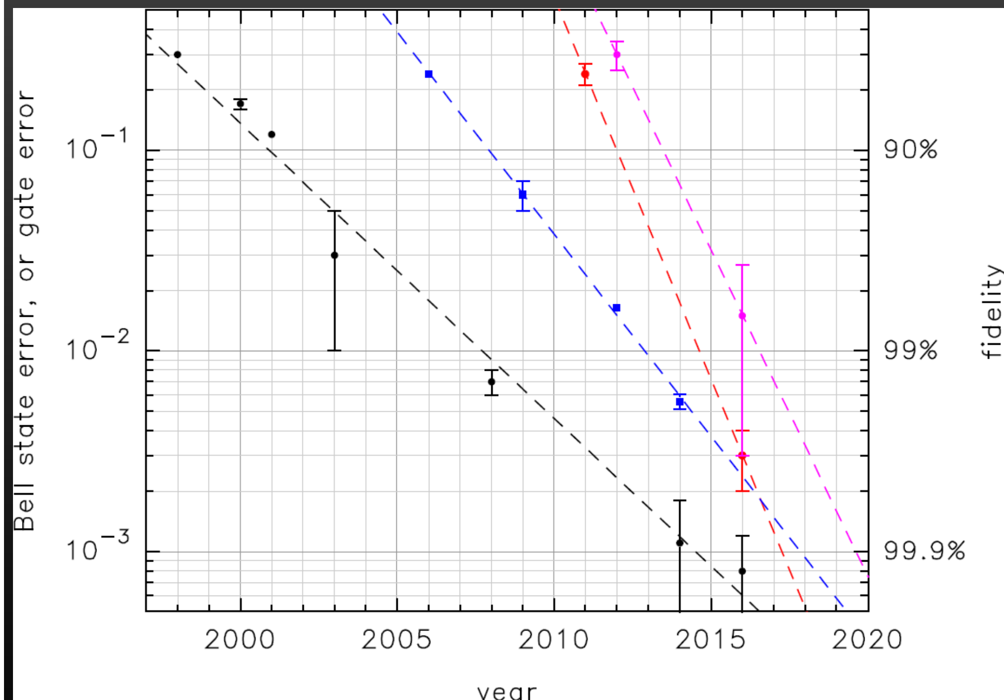
Focus of the last twenty years of research, which continues

Recent focus

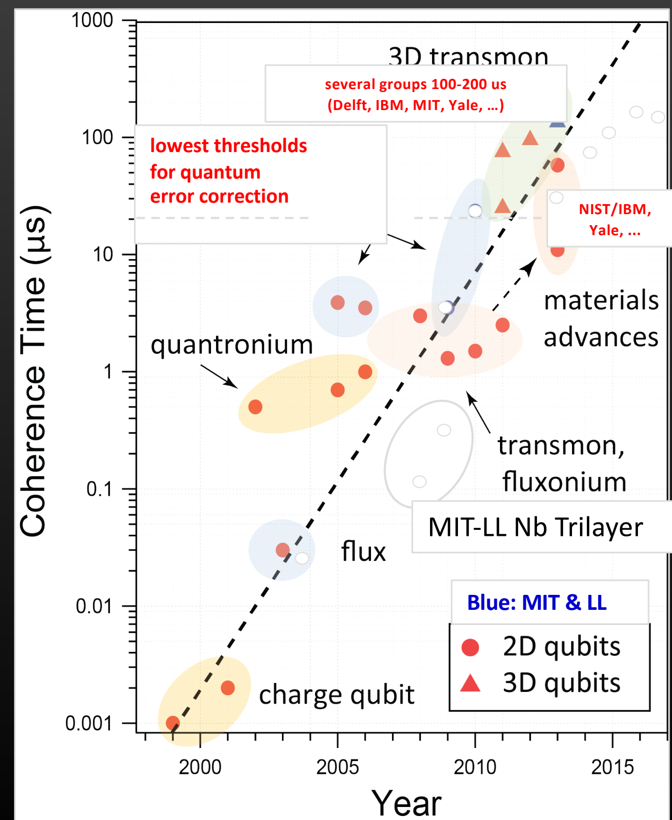
Always searching

Progress

Partial history of two-qubit gate fidelity progress (From: David Lucas, Oxford)



Partial history of coherence improvements in superconducting qubits (From: Will Oliver, MIT)



QST for the workshop

- Quantum Sensors and Precision Measurement
  - Position, Navigation, Timing
  - Gravimeters, magnetometers, …
- Quantum computation
  - Algorithms and applications
  - Testbeds and heuristics
- Entanglement Distribution (Quantum Networks)
  - Sensor arrays
  - Interferometers
- Quantum enabled classical technology
  - Single photon sources and detectors
  - Quantum-limited amplifiers

NASA

- Unique platforms, environments, and operations to advance quantum sensors and precision measurement
  - Weak signals and long observation times (rovers, planetary probes)
  - Position, navigation, timing
- Utilize quantum computing testbeds to discover algorithms and applications and motivate hardware advances
- Distributed entanglement for interferometry
  - Very long baselines
  - Low losses
  - Tests of and discoveries in foundational science
- Quantum enabled classical technology
  - Deep space communications

NASA Strategy

- Leverage the advantage that NASA missions are one-off and developed over many years in a quest to expand horizons
  - Opportunities to insert unique technology solutions
- Partnerships are critical to advance QST for NASA
  - Within the agency
  - Inter-agency
  - Academia, industry
  - International
- Persistence
  - Long term systematic retirement of challenges with the view that there are beyond classical advantages to be gained

Summary

- Much progress has been made in demonstrating basic elements in QST from nearly two-decades of research (Feasibility)
- Much research still to be done and understanding gained to overcome remaining challenges (integration and systems)
- NASA missions and timelines offer many opportunities to realize and take advantage of the beyond classical capabilities of QST
- In the next few years, we will learn about the capabilities and usefulness of testbed quantum computing systems and point the way to applications
- Partnerships and persistence of efforts are critical
- QST is very high risk and likely very high rewards

Thank you!