

Chicago Quantum

US ADVANCED COMPUTING
INFRASTRUCTURE, INC.

Expected Business Value in the Quantum Computing Ecosystem

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Innovations in Quantum Optics and Quantum Computing
March 23-24, 2020, London UK
Longdom Conferences

About the speaker

Jeffrey Cohen is leading a quantum computing consulting startup after 30 years in IT Management Consulting & IT Professional Services.

Jeff was an IBM Executive, Hewlett Packard Director, McKinsey & Company Associate Partner, Siemens Managing Vice President, and KPMG Senior Manager.

Jeff's education includes a BA economics from the University of Chicago, MM Management & Strategy, Finance from Northwestern University (Kellogg), and 4 classes towards a Ph.D. in Management Sciences from Illinois Institute of Technology (Stuart)

Jeff is an IT services innovator whose work grows IT consultancies. His focus is to help clients manage IT infrastructure more efficiently and effectively.

Jeff led progressively larger IT consulting practices (from 11 to 380 consultants and \$3M to \$447M annual sales).



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Groupings and Categories for Providers and Use Cases

Groupings of Quantum Computing Providers

- ❖ Hardware - 1/full stack quantum computer providers, 2/component or solution manufacturers, & 3/start-ups
- ❖ Software platform and tool providers
- ❖ Access providers - multi-vendor
- ❖ Consultancies & ISVs

Use Case Categories:

- ❖ quantum computing: optimization
- ❖ quantum computing: non-optimization
- ❖ quantum technologies (not computing)



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“Contact us for more information or to create your own quantum advantage”

Notes & Acknowledgements

“All data is publicly available”

“All quantum use cases discussed are experimental, POC, and not in production”

“Our lists may not be comprehensive as they are based on team experience & research”

“All providers are listed only once even if they serve multiple markets, in order of hardware, software, access, and consulting-ISV”

“Some providers, and use cases, leverage quantum inspired technologies, including simulation”

Provider data current as of Feb 1, 2020. Use case data current as of Oct 1, 2019.



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Quantum Computing Ecosystem of Providers

Quantum Computing Hardware Platform Manufacturers

- ❖ Alibaba Cloud (with CAS)
- ❖ AQT GmbH
- ❖ ATOS / Bull
- ❖ D-Wave Systems
- ❖ Fujitsu IT Ltd.
- ❖ Google AI
- ❖ Honeywell Quantum Solutions
- ❖ IBM Research
- ❖ IonQ
- ❖ NTT Phi Laboratories
- ❖ Rigetti Computing
- ❖ Xanadu

- ❖ Approaches: 1/ annealing (QUBO & Ising), 2/ universal or gate-based systems, or 3/ simulators (full stack)
- ❖ Technologies: Current: superconducting, ion traps, & photonics. Future: neutral atoms, CMOS, spin & topological qubits
- ❖ Access methods: 1/ on-premise hardware, or 2/ public cloud access
- ❖ Simulators currently offer comparable performance
- ❖ Competition between F100 public and small VC/ private firms
- ❖ No commercial 'production' workloads

* Excludes start-ups without a demonstrated hardware platform (e.g., PsiQuantum).

* Most providers build or systems integrate a full hardware and software stack (think IBM PCs before MS/DOS), with some recent software and access cross-compatibility.

* No supplier offers quantum memory, storage, I/O, networking or DBMS; nor fault tolerant or error corrected systems.

Quantum Hardware Component or Solution Manufacturers

- ❖ Bluefors
- ❖ Cold Quanta
- ❖ Hitachi Cambridge Labs
- ❖ ID Quantique
- ❖ Infineon Technologies
- ❖ Intel Corporation
- ❖ InfiniQuant
- ❖ M Squared
- ❖ Quandela
- ❖ QuiX
- ❖ Qunnect
- ❖ Silicon Quantum Computing
- ❖ Toshiba Research Europe Limited

- ❖ A growing ecosystem of component makers (and we recognize this is an incomplete list)
- ❖ Significant efforts creating quantum processing units (CPUs for quantum computing)
- ❖ Existing component makers extending addressable market into quantum computing
- ❖ Mix of academic spinoffs, large corporate research groups, and small startups.
- ❖ Growing number of quantum safe communications solutions (e.g., QKD)

* No supplier offers quantum memory, storage, I/O, networking or DBMS; nor fault tolerant or error corrected systems.

* Includes primarily QPU, QKD and system component manufacturers (e.g., dilution refrigerators). Excludes Cryogenic DRAM providers (2)

Quantum Computing Hardware Start-ups

- ❖ Atom Computing
- ❖ Bleximo
- ❖ BraneCell
- ❖ IQM OY
- ❖ ORCA Computing
- ❖ Pasqal
- ❖ PSI Quantum
- ❖ Quantum Circuits Inc.
- ❖ Quantum Motion (TBC)

- ❖ Technology: 1/ neutral atoms, 2/ photonics, or 3/CMOS (current CPU technology) to improve scalability
- ❖ Some firms are lightly funded (small ranges from \$1.5M to \$20M)
- ❖ Largest funding is \$230M for PsiQuantum, which rivals corporate research scale
- ❖ Quantum Circuits is a Microsoft Quantum Azure partner

Quantum Computing Software Platform & Tools Providers

- ❖ IQBit
- ❖ Aliro
- ❖ Artiste
- ❖ Cambridge Quantum Computing
- ❖ ETH Zurich (Project Q)
- ❖ ISARA Corporation
- ❖ QuTech
- ❖ Q-CRTL
- ❖ Quantum Benchmark Inc.
- ❖ Riverlane
- ❖ Strangeworks

- ❖ Some firms are targeting the quantum computing industry to help manufacturers scale
- ❖ Some firms target developers and enterprise customers looking to adopt quantum computing with simulation and cross-platform software and algorithms
- ❖ One provides post quantum cryptography software (and consulting / project services)
- ❖ One is offering a scalable quantum simulator (without a bundled hardware capability)
- ❖ All are small VC/private/spinout firms

Quantum Computing Multi-Vendor Platform Access

- ❖ Amazon Web Services / Braket
 - ❖ Microsoft Azure Quantum
 - ❖ QC-Ware
- ❖ AWS and Microsoft offer a full set of services along with quantum computing platform access
 - ❖ QC-Ware offers software and consulting services in addition to cross-platform quantum computing access
 - ❖ We see this emerging capability of providing multi-vendor platform access continuing

* We exclude providers that offer access to their own platforms only, or were mentioned as offering their own platforms (e.g., Google, IBM & Rigetti)

Quantum Computing Consultancies & ISVs

- ❖ Accenture Research
- ❖ Boston Consulting Group
- ❖ Chicago Quantum
- ❖ h-Bar Quantum Consultants
- ❖ Max Kelsen
- ❖ QuantFi
- ❖ Zapata Computing

- ❖ We acknowledge this list is incomplete, and is based on our own experience and access to firm members
- ❖ Typically small teams serving clients around specific use cases (e.g., chemistry, financial services), whether independent or within larger firms
- ❖ Teams require diverse skillsets (physics, computer science, mathematics, industry domain, functional domain) and typically require programming and algorithm skills.

- * We see research and speakers from both Accenture and Boston Consulting Group on the conference circuit.
- * We have met with Zapata, QuantFi, Max Kelsen, and h-Bar in our daily work.

Early Quantum Use Cases

Demonstrated Early Use Case List: Optimization

- ❖ Optimizing travel routes
- ❖ Optimizing vehicle dispatch
- ❖ Online new car ordering configurator (recommender system)
- ❖ Analysis to increase automotive paint line capacity
- ❖ Waste & recycling truck scheduling
- ❖ Ordering items for sale on a website
- ❖ Digital advertisement recommender
- ❖ Portfolio optimization to minimize risk or cost vs. expected return
- ❖ Scheduling robots to seal joints and seams
- ❖ Scheduling complex repair shops

Demonstrated Early Use Case List: Non-Optimization

- ❖ Verification & Validation
- ❖ Molecule and material discovery (structure, function and comparisons) for batteries, pharmaceuticals, and commercial compounds.
- ❖ Accurate calculation & prediction of molecular properties (included excited states and chemical reactivity)
- ❖ Price equities, options and derivatives (e.g., quantum monte carlo)*
- ❖ MRI scanner improvements (faster and/or more sensitive)
- ❖ Quantify client risk in new ways
- ❖ Radio Access Network signal processing (connect mobile user device to core network)

Demonstrated Early Use Case List: Quantum Technologies

- ❖ Secure terrestrial communications from space
- ❖ Enhanced radar detection
- ❖ Navigation without GPS
- ❖ Ultra-secure communications w/ photonics codes (Quantum Key Distribution)
- ❖ Another way to securely communicate (via the Earth's magnetic field)
- ❖ Detect movement and activity (over long distances) and within the human body
- ❖ Picking lottery winners (QRNG ensures randomness)
- ❖ Atomic Clocks (very accurate)
- ❖ Better TVs, LED displays, and lighting solutions (using quantum dots)

Commercial Enterprise Adoption

Commercial Enterprise Client Approaches

- ❖ Begin to learn about quantum computing
- ❖ Build your team of evangelists or volunteers
- ❖ Identify and focus on one use case that would create significant value
- ❖ Tap into the industry providers, academic institutions, scientific labs and research groups; make investments in learning, research & development
- ❖ Be visible, open and collaborative in your efforts

Conclusions & Synthesis