QA for the Enterprise: Platform and Applications

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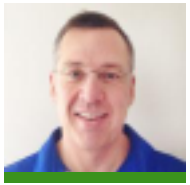
QC WARE OVERVIEW

Mission:	Solve real-world problems with QC resources
Technology partners:	NASA, D-Wave, USRA, Stanford, Fortune 500 companies
Office location:	NASA Research Park, Mountain View, CA
Team:	12 scientists and engineers + senior advisors
Machine access:	Access to multiple D-Wave systems

TEAM

Unrivaled Talent & Experience



Matt Johnson - CEO

MBA @ Wharton
BS @ USAF Academy

Asier Ozaeta

PhD @ UPV (Spain)
Condensed Matter Physics

Kin-Joe Sham - COO

PhD, MBA @ UMN
BS, MEng @ MIT
Electrical Engineering

Randall Correll – Sr. Sci.

PhD @ UT Austin
Theoretical Physics

Peter McMahon

PhD, MS @ Stanford
Quantum Info Sciences

Karthik Choutagunta

PhD candidate @ Stanford
Electrical Engineering

Shreyas Parthasarathy

BS candidate @ Berkeley
Engineering Physics

Vincent Su

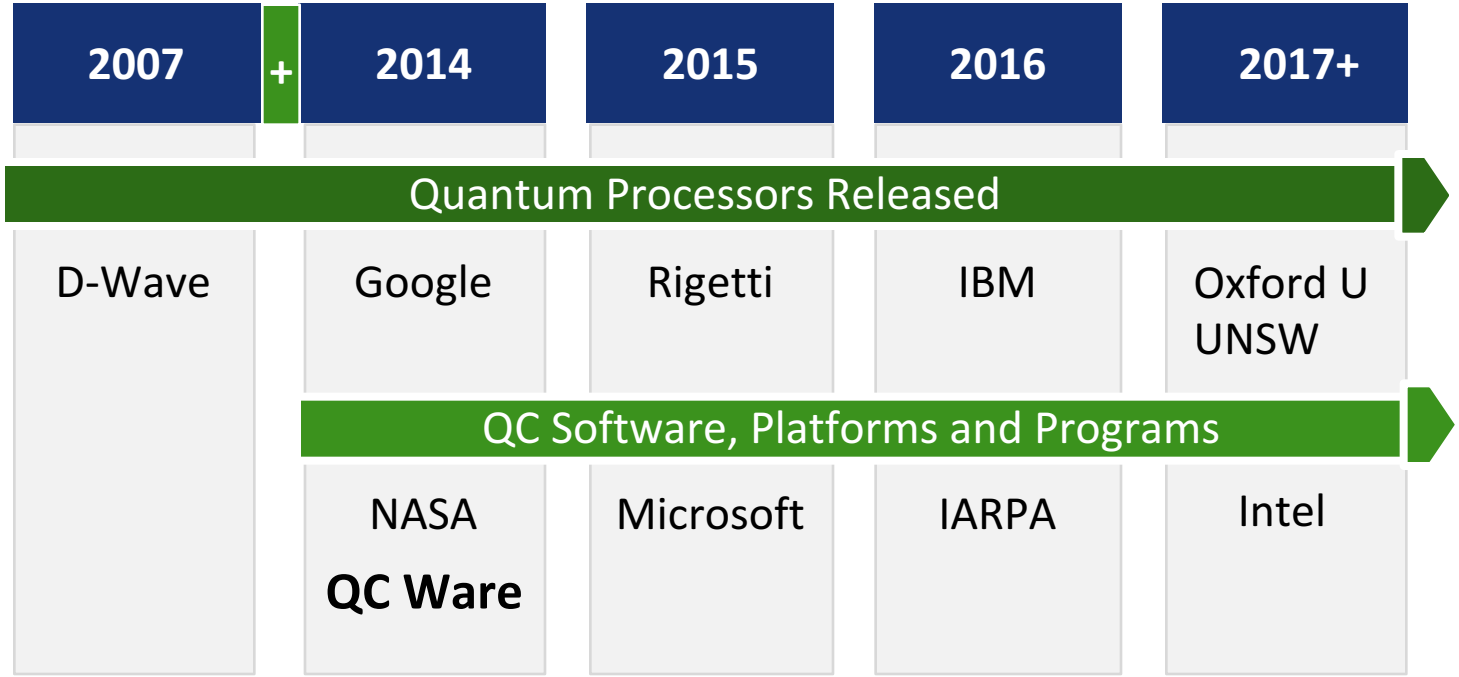
MS, BS candidate @ Stanford
Physics and CS

Alejandro Perdomo-Ortiz

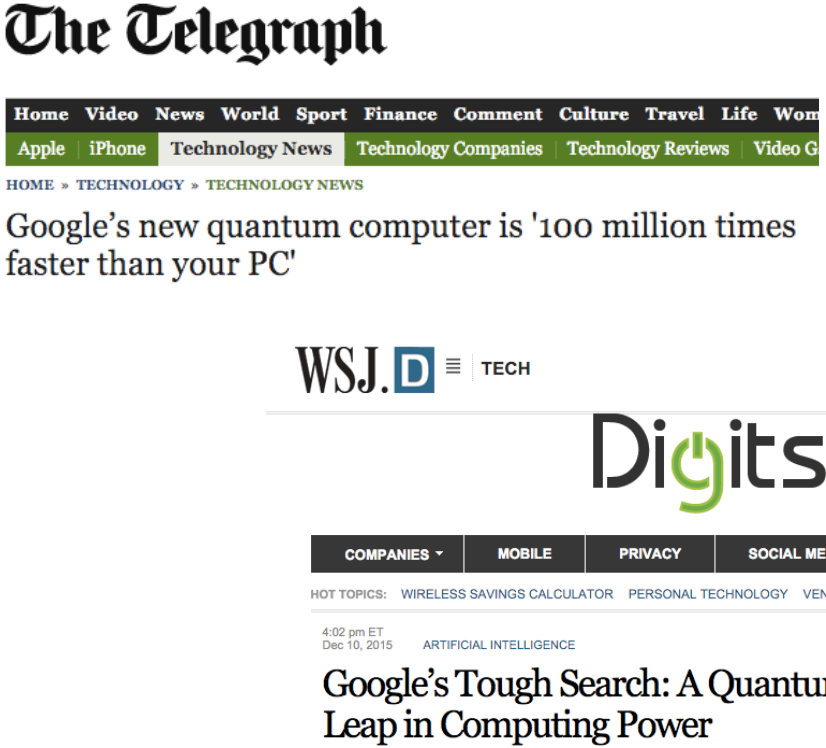
Sci. Advisor

MS, PhD @ Harvard
Computational Physics

QC ECOSYSTEM MILESTONES …



GOOGLE'S BENCHMARKING ANNOUNCEMENT



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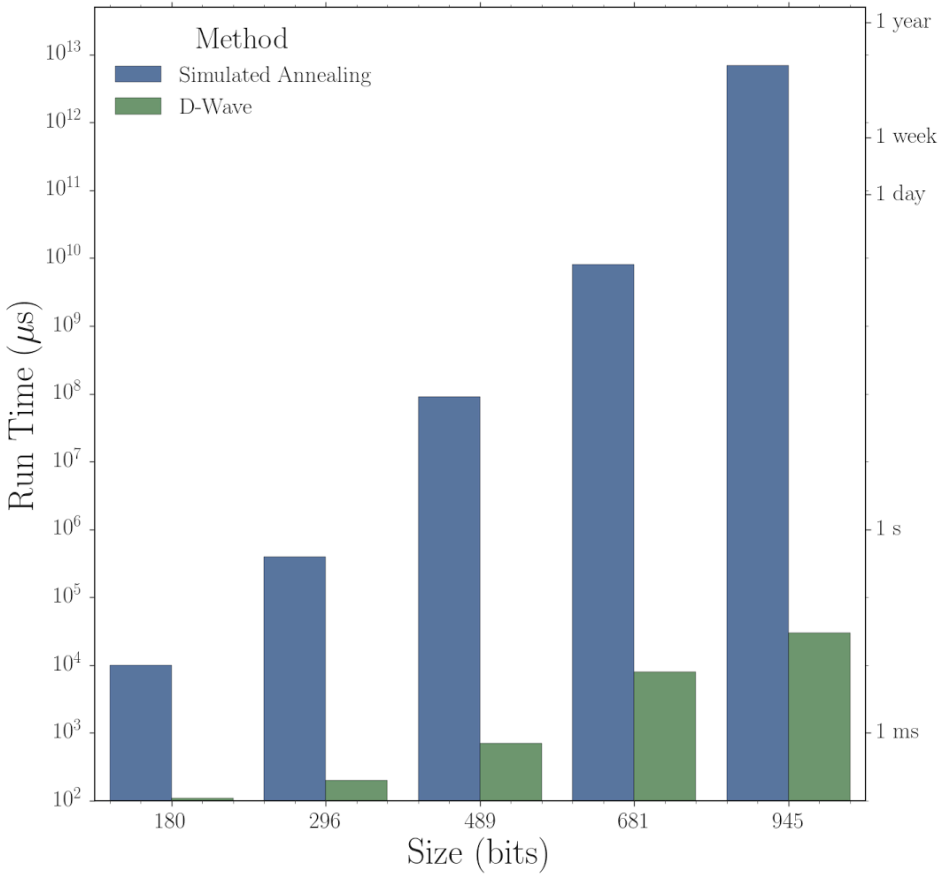
MIT Technology Review

Computing

Google Says It Has Proved Its Controversial Quantum Computer Really Works

QUANTUM ANNEALING – SPEED ADVANTAGE

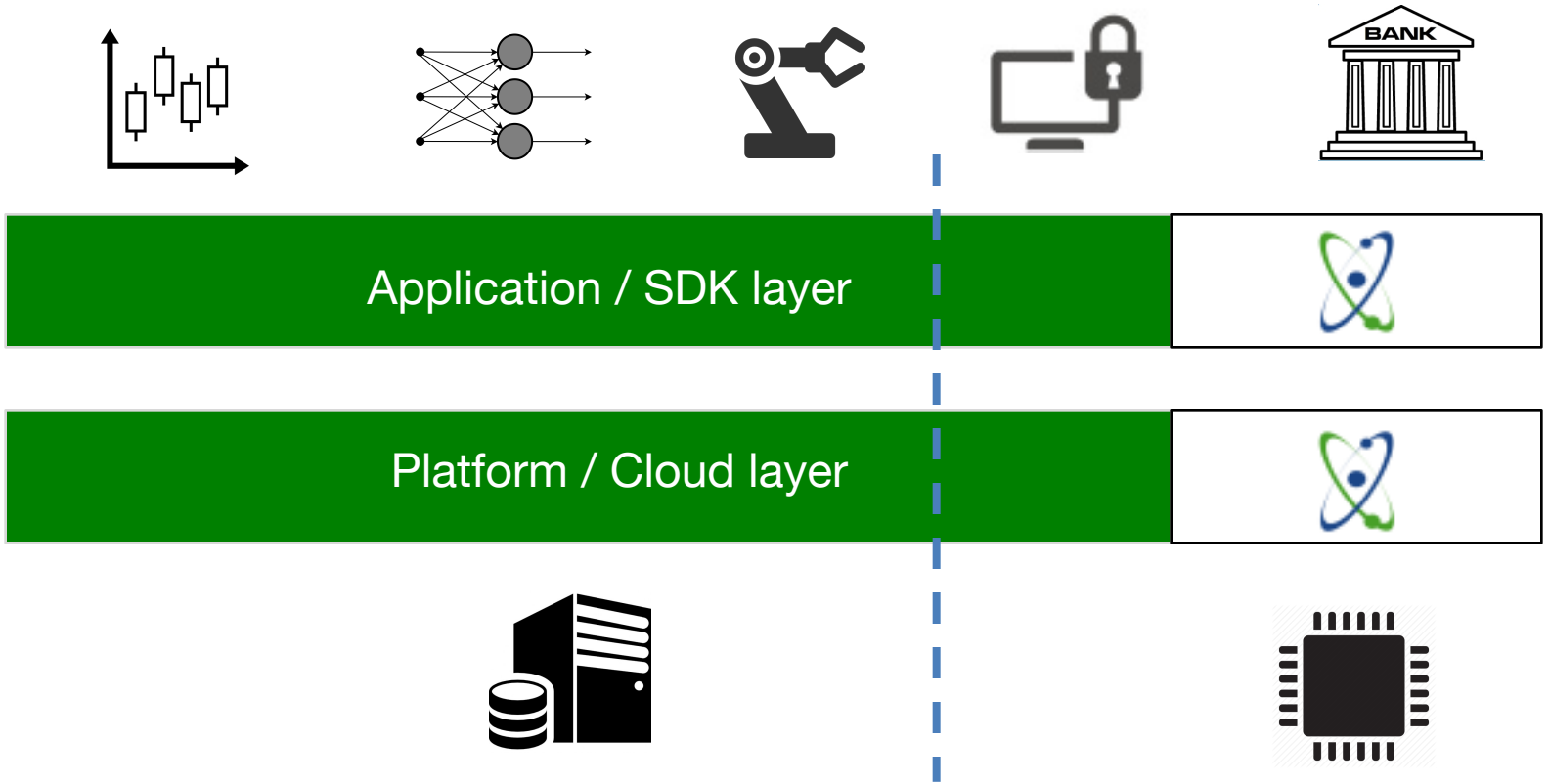


- The smallest problem size takes ~ 10 milliseconds for SA and a fraction of one millisecond for the D-Wave machine.
- For a problem that's only ~5 times larger, the SA approach takes over a year, whereas the D-Wave requires less than a second.

NEAR-TERM PERFORMANCE BY DESIGN

- Decompose problem at formulation level
- Avoid full-connectivity, if possible
- Avoid ancillary variables, if possible
- Decompose problem at QUBO level
- Post-process to pull best answers from spectrum of solutions

PLATFORM STACK



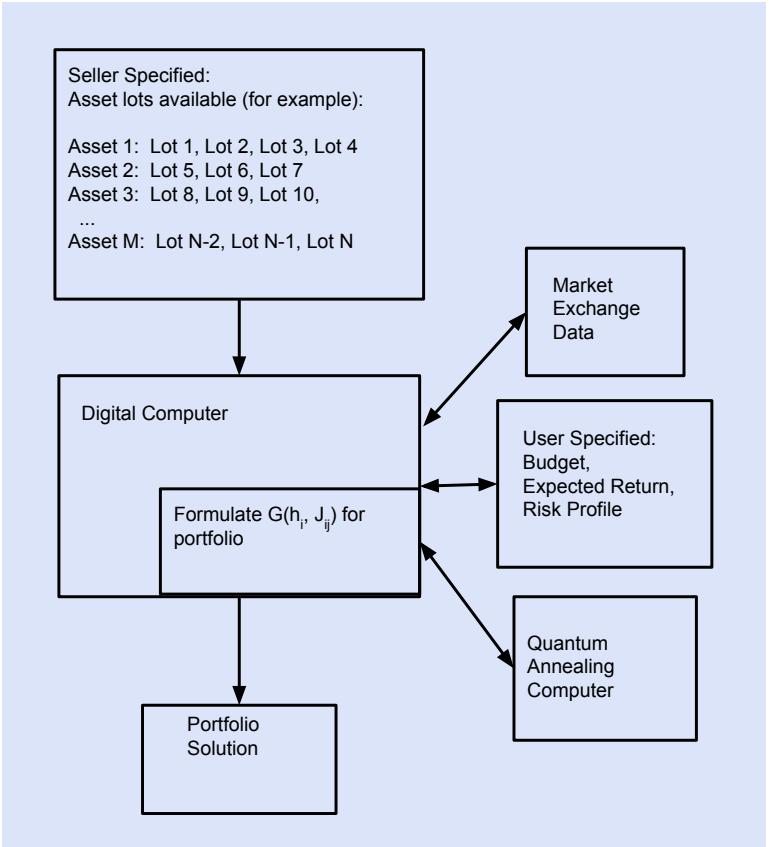
QC WARE PLATFORM OBJECTIVES

High-Performance Applications	• Deep learning, cybersecurity, quant finance • Apps run on QC Ware platform
Full SDK Suite	• Simplify programming experience for novice QC users
Hardware-Agnostic Acceleration Platform	• Obtain optimal performance with no manual fine-tuning (for D-Wave and other QC hardware systems)

QA APPLICATION MODES

- Optimality
- Time-to-Target
- Sampling

Example: Portfolio Optimization



$$G = \sum_i h_i s_i + \sum_{i<j} J_{ij}\, s_i s_j$$

$$G = \mathrm{f_{pr}} G_{past\ return} + \mathrm{f_{er}} G_{expected\ return} + \mathrm{f_c} G_{cost}$$

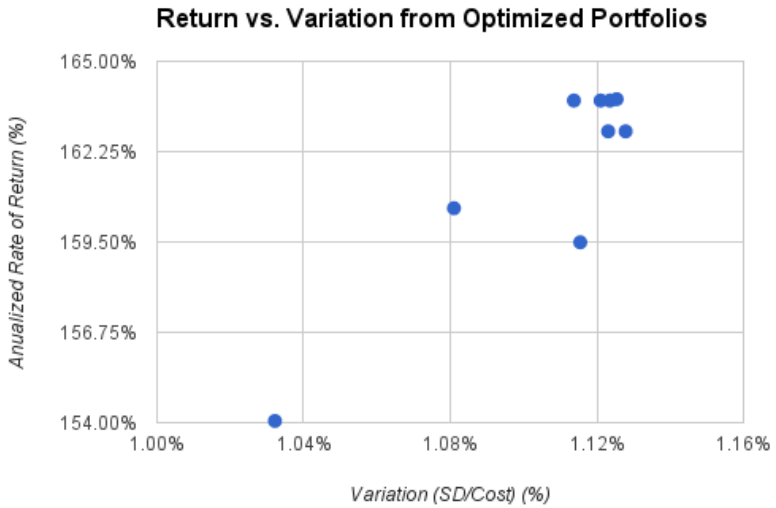
$$r_i(t_0) = (p(t_0) - p(t_{-1}))/p(t_{-1})$$

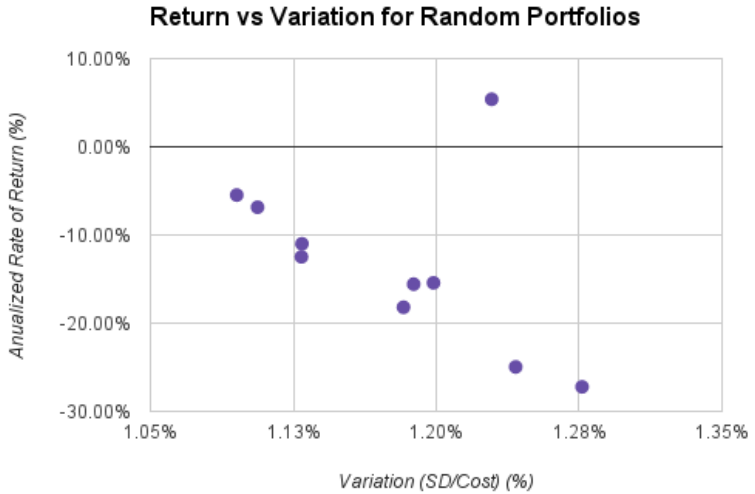
$$G_{past\ return} = \sum_i p_i^2\, \mathrm{Var}[r_i] s_i + \sum_{i<j} 2 p_i p_j \mathrm{Cov}[r_i, r_j] s_i s_j$$

$$G_{cost} = -2\mathrm{C} \sum_i p_i s_i + \left(\sum_i p_i s_i\right)\left(\sum_j p_j s_j\right)$$

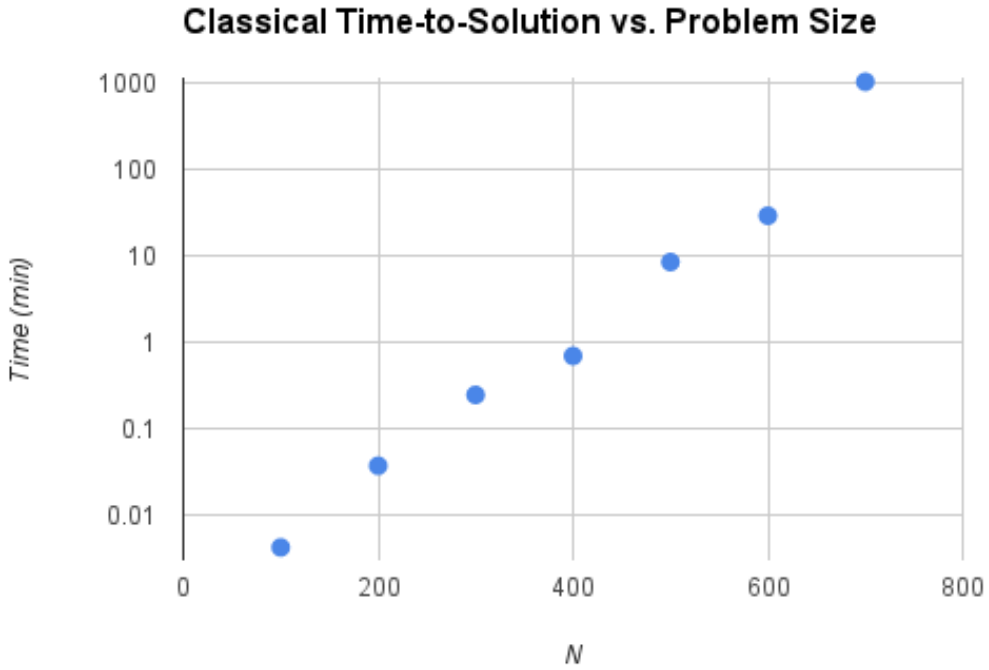
$$G_{expected\ return\ (max)} = \sum_i E_i\, s_i$$

Optimized versus Random Portfolios





Example: Portfolio Optimization Classical Performance



Approximate classical time-to-solution (min.) versus problem size for fully-connected QUBO problems using CPLEX default settings on a quad-core CPU.

Take Aways

- Now is the time to begin developing applications
- Work with enterprises to focus on relevant problems
- Success breeds success; Apps breed more apps
- Design apps that perform on near-term hardware
- A useful algorithm is valuable on quantum or classical hardware