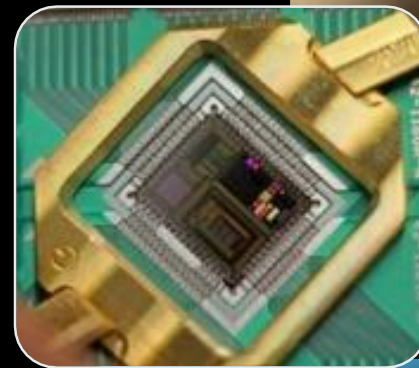


Quantum Computing and D-Wave

April 2016

What is a Quantum Computer?

- Exploits quantum mechanical effects
- Built with “qubits” rather than “bits”
- Operates in an extreme environment
- Enables quantum algorithms to solve very hard problems



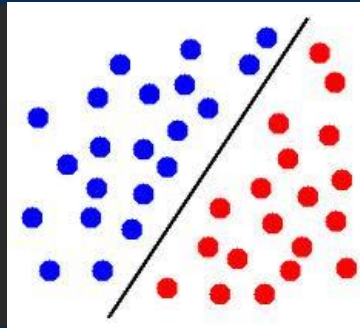
Quantum Processor

Characteristics of Classical Digital Systems

Binary

```
0100011101110  
1010111001001  
1101010010000  
0010000100111
```

Separable



Barriers



Quantum Effects

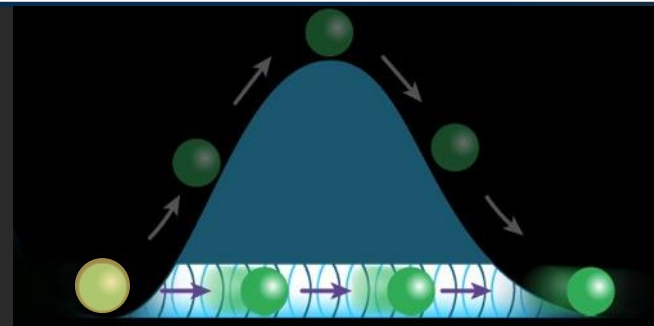
Superposition



Entanglement

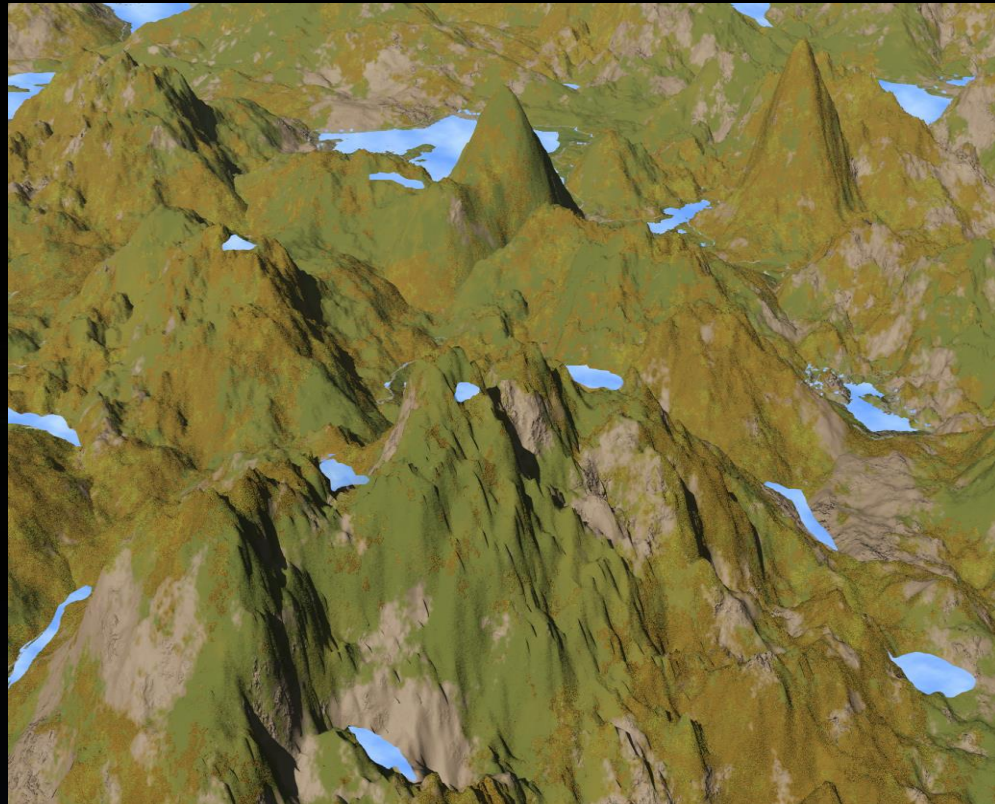


Quantum Tunneling



Energy Landscape

- Space of solutions defines an energy landscape & best solution is **lowest** valley
- Classical algorithms must **walk over** this landscape
- Quantum annealing uses **quantum effects** to go *through* the mountains

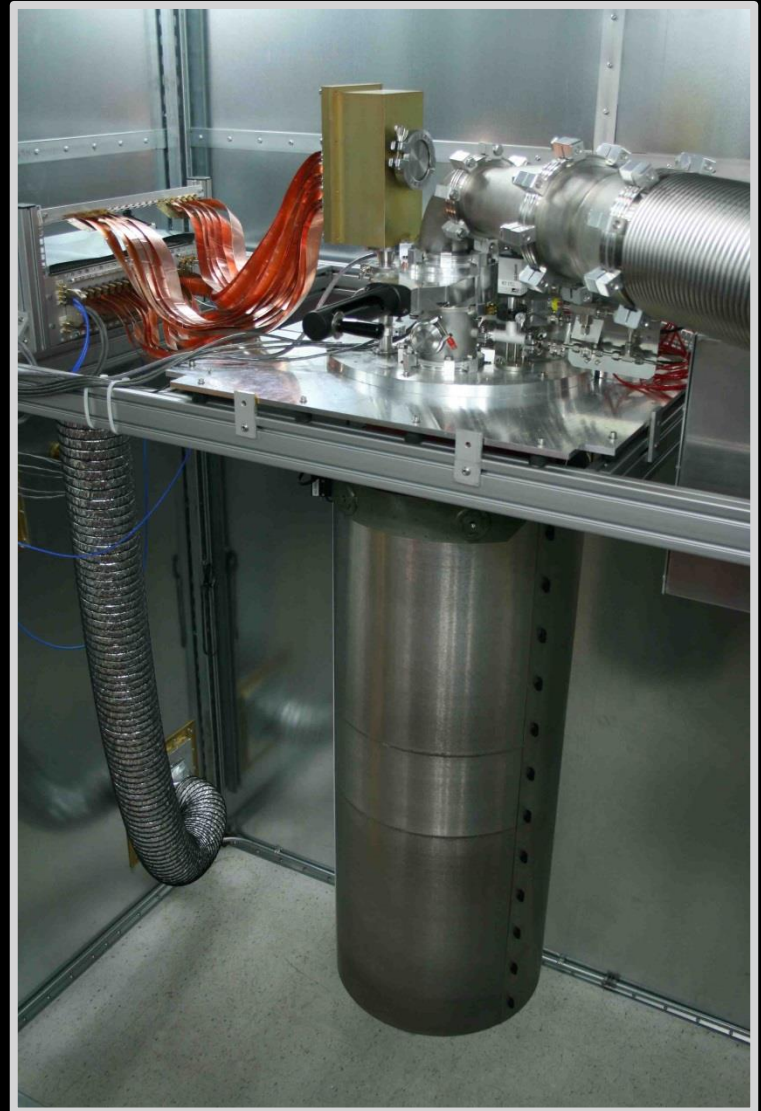


D-Wave Container - "SCIF-like" - No RF Interference



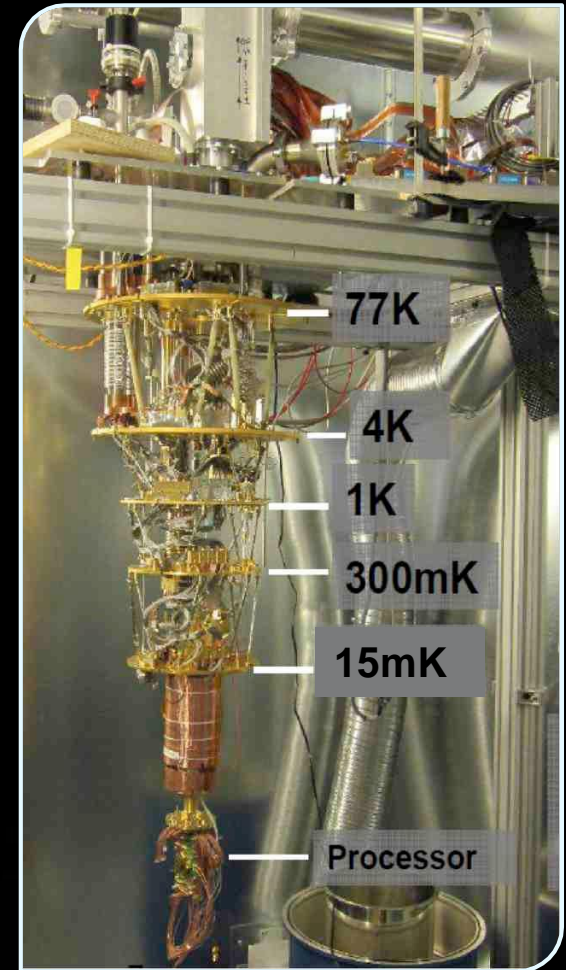
System Shielding

- ~16 layers of shielding between QPU and outside world

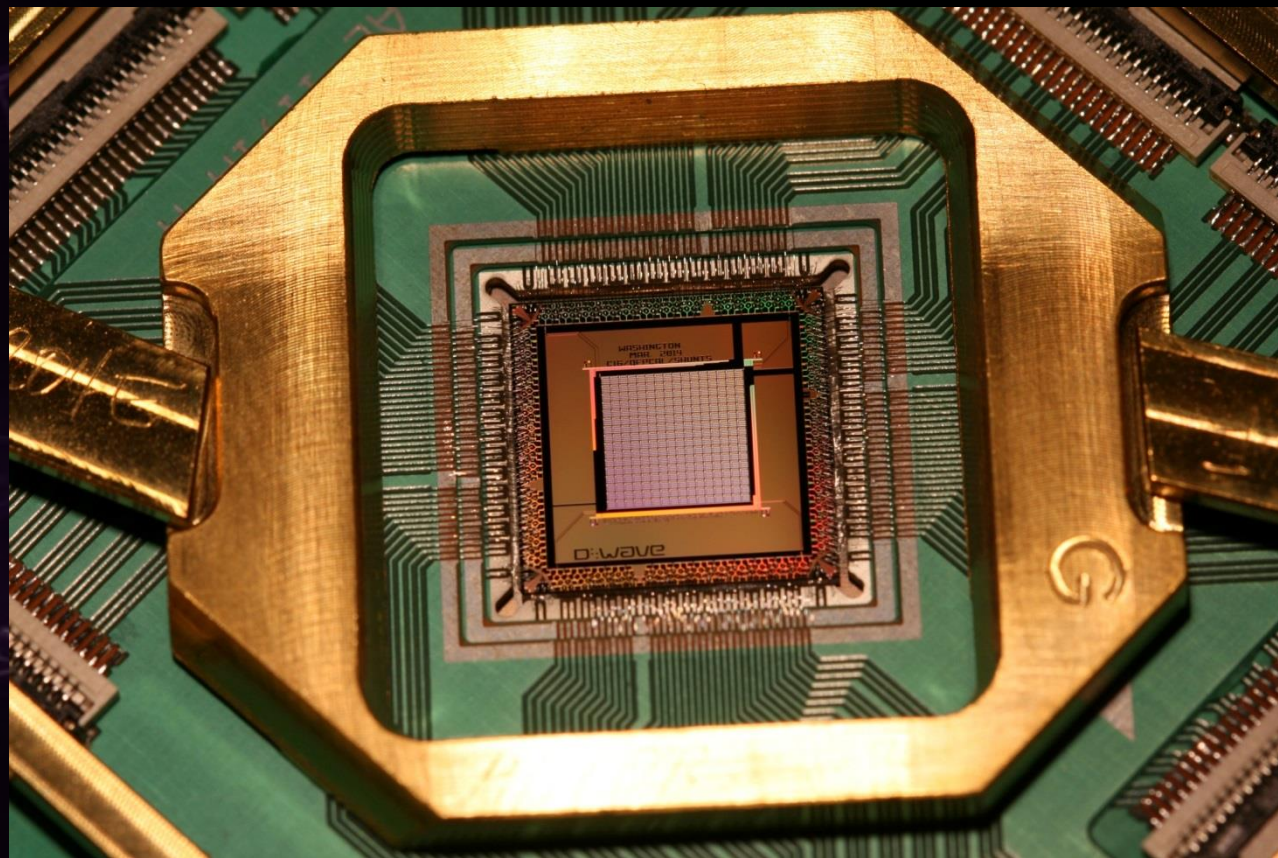


Processor Environment

- Cooled to 0.015 Kelvin, 175x colder than interstellar space
- Shielded to 50,000 × less than Earth's magnetic field
- In a high vacuum: pressure is 10 billion times lower than atmospheric pressure
- On low vibration floor
- <25 kW total power consumption – for the next few generations

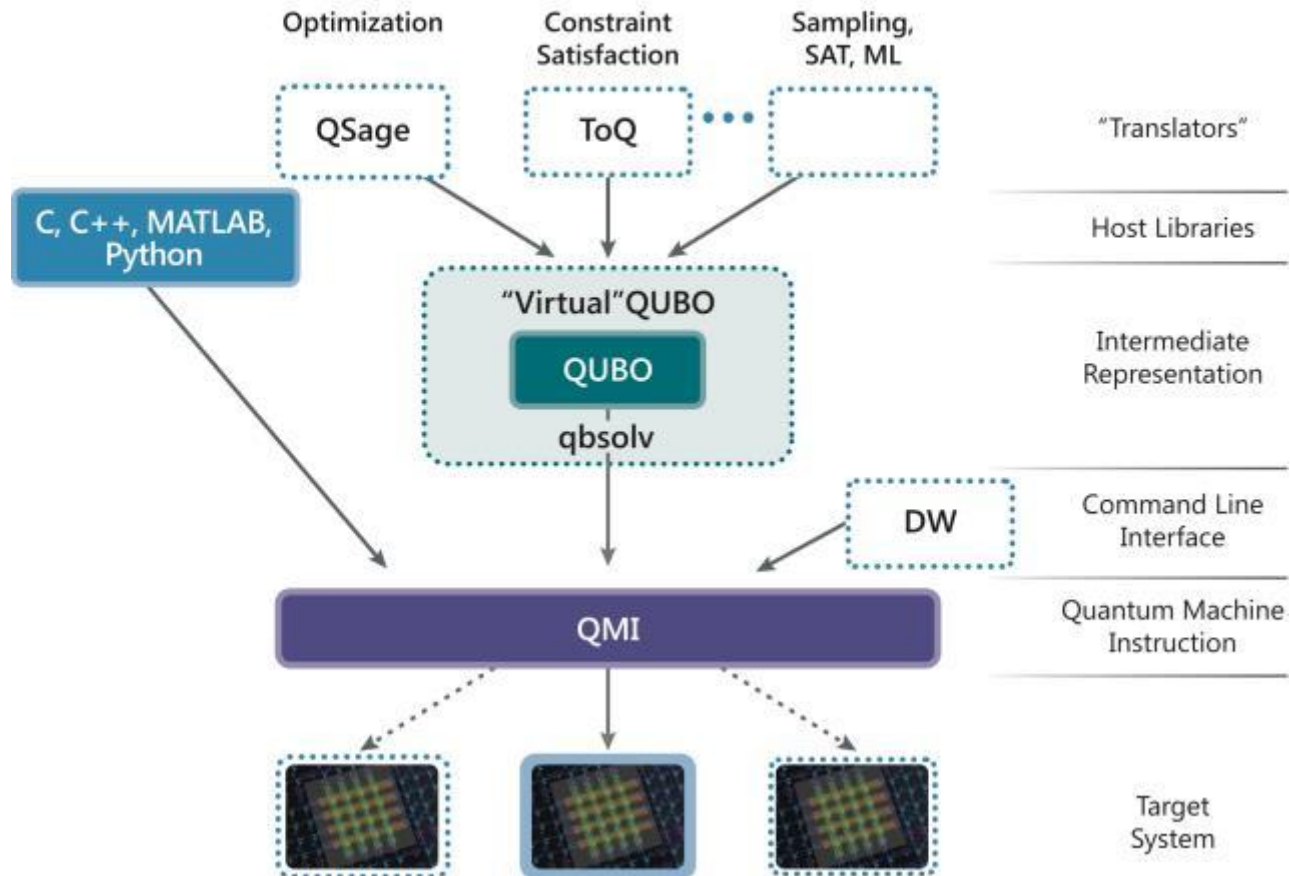


D-Wave 2X Quantum Processor



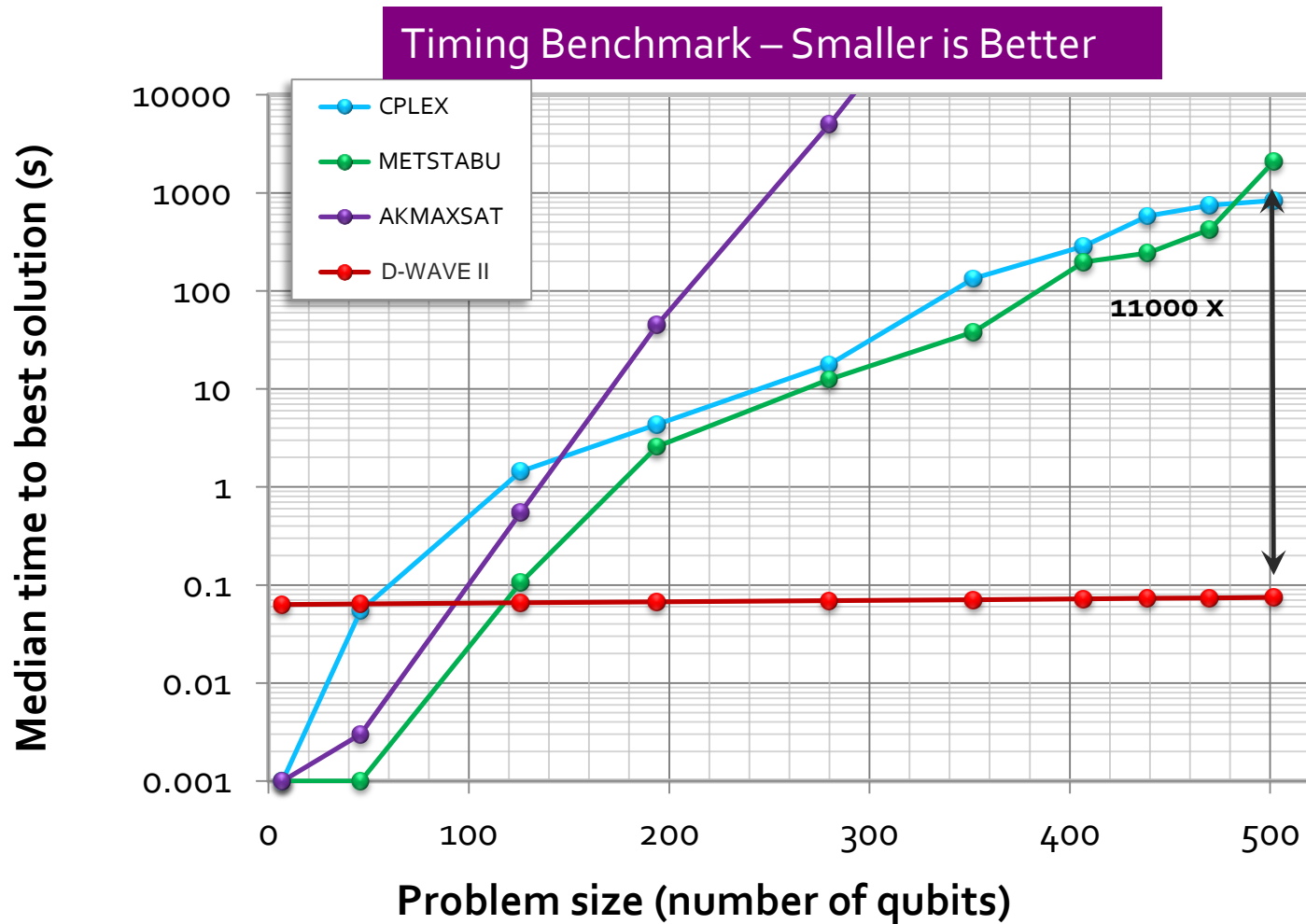
D-Wave Software Environment

D-Wave Software Environment



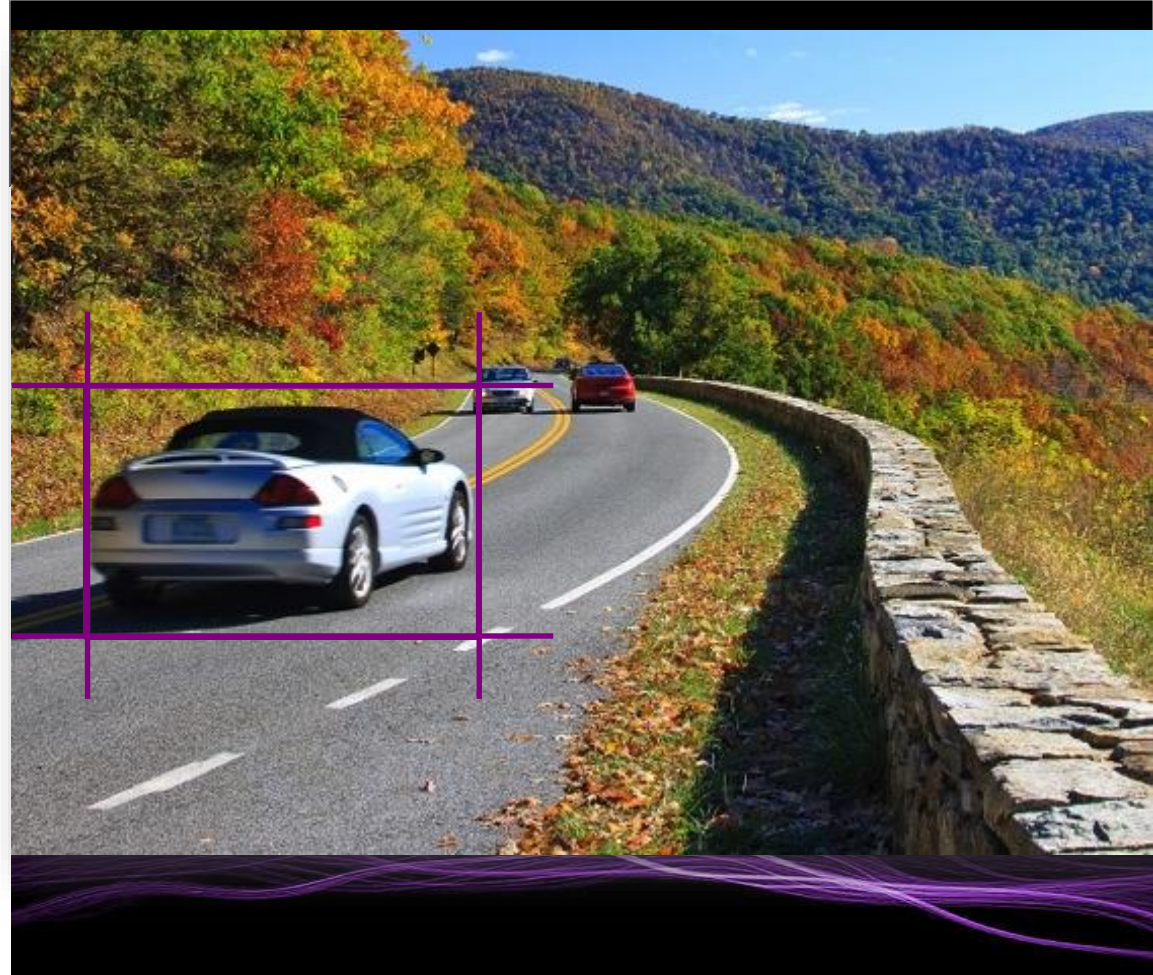
Discrete Combinatorial Optimization Benchmarks

Median Time to Find Best Solution



Machine Learning: Binary Classification

- Traditional algorithm recognized car about 84% of the time
- Google/D-Wave Qboost algorithm implemented to recognize a car (cars have big shadows!)
- “Quantum Classifier” was more accurate (94%) and more efficient
- Ported quantum classifier back to traditional computer, more accurate and fewer CPU cycles (less power)!



Google Blog December 8, 2015

When can Quantum Annealing win?

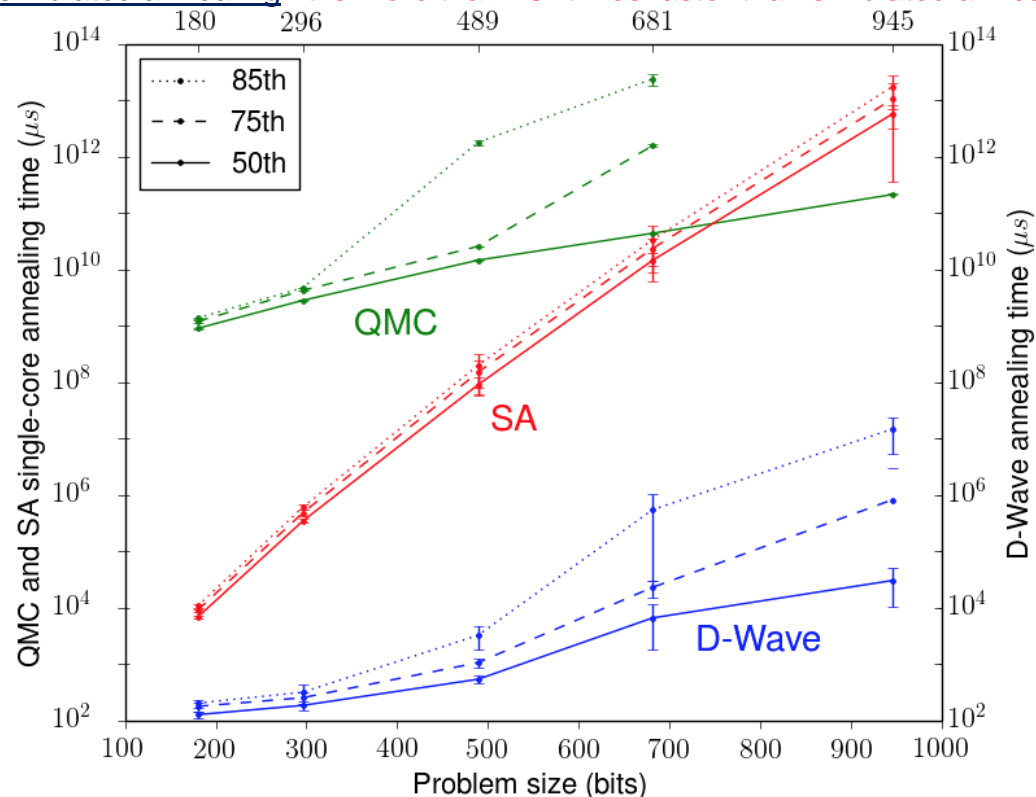
Tuesday, December 08, 2015

<http://googleresearch.blogspot.ca/2015/12/when-can-quantum-annealing-win.html>

Posted by Hartmut Neven, Director of Engineering

During the last two years, the Google [Quantum AI team](#) has made progress in understanding the physics governing [quantum annealers](#). We recently applied these new insights to construct proof-of-principle optimization problems and programmed these into the [D-Wave 2X quantum annealer](#) that Google operates jointly with NASA. The problems were designed to demonstrate that quantum annealing can offer runtime advantages for hard optimization problems characterized by rugged energy landscapes

We found that for problem instances involving nearly 1000 binary variables, quantum annealing significantly outperforms its classical counterpart, [simulated annealing](#). **It is more than 10^8 times faster than simulated annealing running on a single core.**



The Most Advanced Quantum Computer in the World

