QC Ware

Enterprise solutions for quantum computing

Matt Johnson
CEO

Vic Putz
Head of Engineering

QC Ware at a Glance

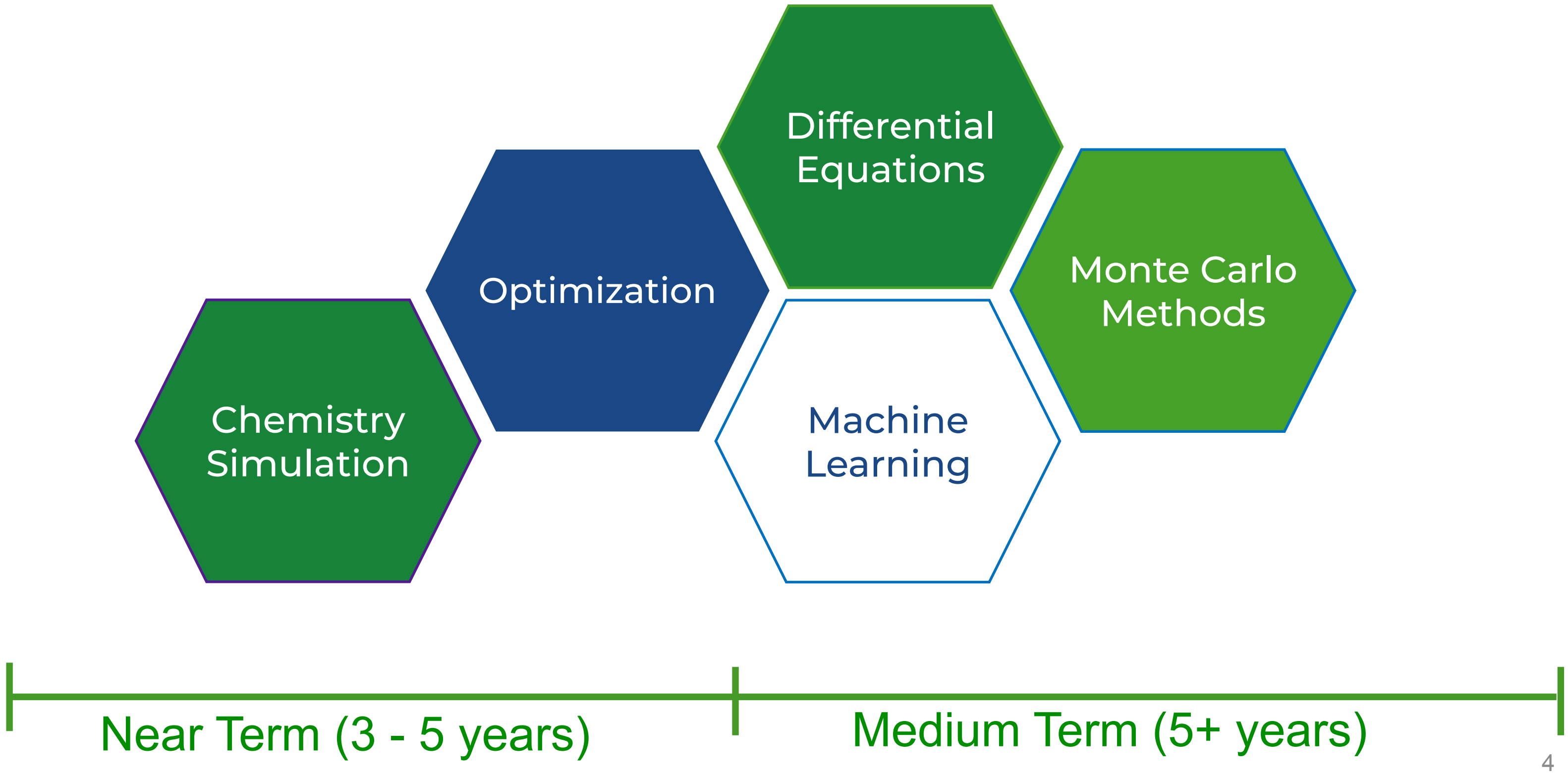
Enterprise Solutions for Quantum Computing

- **Company:**
  - Founded: 2014 / Series A: $6.5M, 2018
  - Investors: Goldman Sachs, Citi, D.E. Shaw, Airbus
  - Government Grants: NSF, DoE, US Air Force
  - Enterprise Customers: Airbus, BMW Group, Equinor, Aisin and add'l F200 corporates
- **Expertise/Differentiation:**
  - Algorithm design for near-term hardware
- **Product:**
  - "Forge" - A data science platform for quantum computing
- **Services:**
  - Workshops / Pilot Projects / Algorithm Design
- **Locations:**
  - Palo Alto, CA / Paris, France / Tokyo, Japan (expected 2020)
- **Events:**
  - Q2B Conference – Announcements for major developments in QC

We Build
Quantum Algorithms

QCWARE

Problem Classes



Meet the QC Ware Team


Matt Johnson


KJ Sham


Randy Correll


Scott Aaronson


Wim van Dam


Iordanis Kerenidis


Yianni Gamvros


Peter McMahon


Adam Bouland


Bryan Burr


Robert Parrish


Vic Putz


Anupam Prakash


Fabio Sanches


Juan Adame


Asier Ozaeta


Joe Iosue


Timothy Cui


Stanford Schor


Sean Weinberg

US Office
Palo Alto, CA

EU Office
Paris

Asia Office
Tokyo
(expected 2020)

And now for something... completely different

A Quick Overview of Quantum Computing

(for normal humans)

Plus an overview of important algorithms
and some applications to space

Vic Putz, Head of Engineering, QC Ware

Quantum computing is a field that can unfortunately lend itself to hype...

March 2018...

The Register®
Biting the hand that feeds IT

Emergent Tech

'Quantum supremacy will soon be ours!', says Google as it reveals 72-qubit quantum chip

Don't panic: 'supremacy' is the point at which quantum kit trumps classical computers

By Richard Chirgwin 6 Mar 2018 at 08:36 41 SHARE ▼

Quantum computing is a field that can unfortunately lend itself to hype...

March 2018...

The Register®
Biting the hand that feeds IT

Emergent Tech

'Quantum supremacy will soon be ours!', says Google as it reveals 72-qubit quantum chip

Don't panic: 'supremacy' is the point at which quantum kit trumps classical computers

By Richard Chirgwin 6 Mar 2018 at 08:36 41 SHARE ▼

...Oct 2019

GOOGLE \ SCIENCE \ TECH

Google confirms 'quantum supremacy' breakthrough

Its research paper is now available to read in its entirety

By Jon Porter | @JonPorty | Oct 23, 2019, 6:31am EDT

Quantum computing is a field that can unfortunately lend itself to hype...

March 2018...

The Register®
Biting the hand that feeds IT

Emergent Tech

'Quantum supremacy will soon be ours!', says Google as it reveals 72-qubit quantum chip

Don't panic: 'supremacy' is the point at which quantum kit trumps classical computers

By Richard Chirgwin 6 Mar 2018 at 08:36 41 SHARE ▼

...Oct 2019...

GOOGLE \ SCIENCE \ TECH

Google confirms 'quantum supremacy' breakthrough

Its research paper is now available to read in its entirety

By Jon Porter | @JonPorty | Oct 23, 2019, 6:31am EDT

...Jan 2020...

Google "quantum supremacy" "google"

All News Videos

About 786,000 results (0.52 seconds)

So what is “quantum supremacy”?

So what is “quantum supremacy”?

“… the potential ability
of quantum computing ...
to solve problems
that classical computers
practically cannot”

So what is “quantum supremacy”?

“… the potential ability of quantum computing ... to solve problems that classical computers practically cannot”

…which honestly isn’t that helpful.

So let’s have a look at *why* a quantum computer is different… and why you should care.

Let’s start… with logic

For a technical audience, most people would identify boolean logic with:

Let’s start… with logic

For a technical audience, most people would identify boolean logic with:

- Two *values* (0/1, true/false, on/off)

Let’s start... with logic

Most technical people would identify boolean logic with:

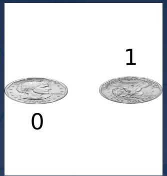
- Two *values* (0/1, true/false, on/off)

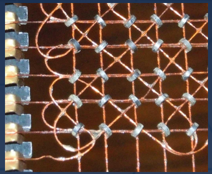
- Some *operations* on those values (OR, AND, NOT--truth tables?)

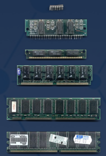
Let’s start... with logic

To make a *computer*, you add a physical implementation of these:

- Two *values* (0/1, true/false, on/off)--*represented by*







- Some *operations* on those values (OR, AND, NOT)--*implemented by*

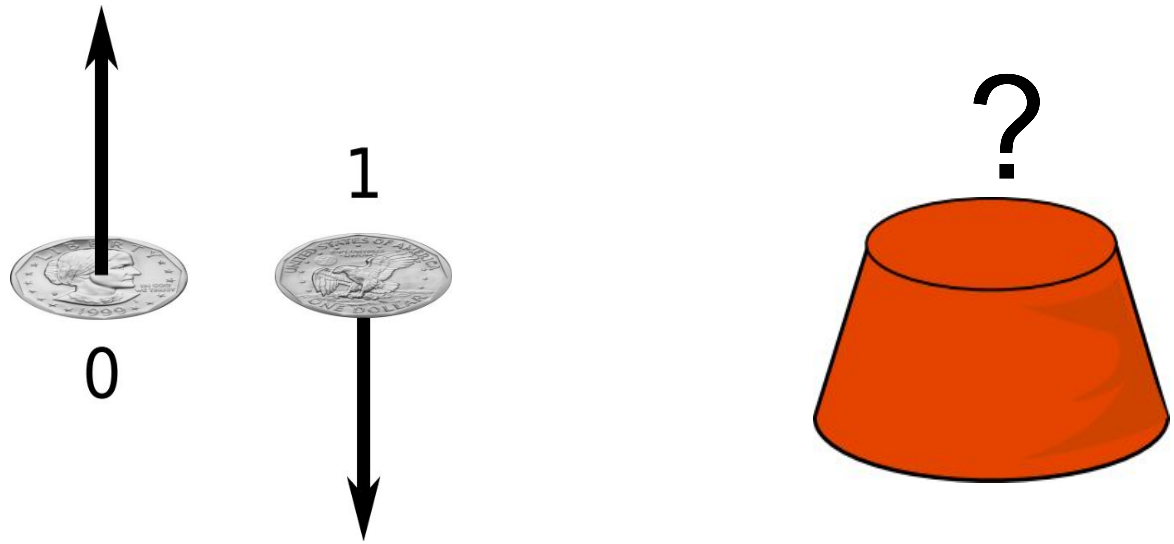
Flip a Coin

Reverse a B-field

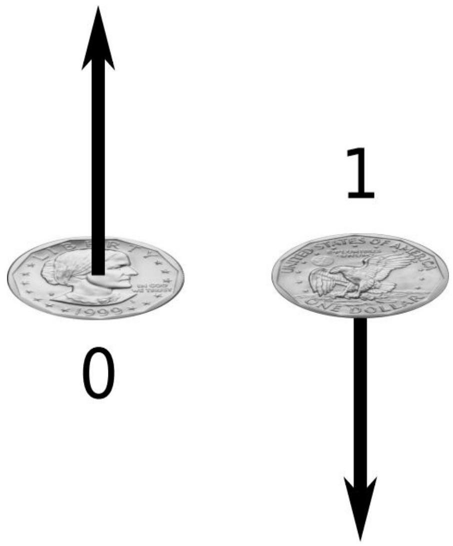
Change a capacitor charge

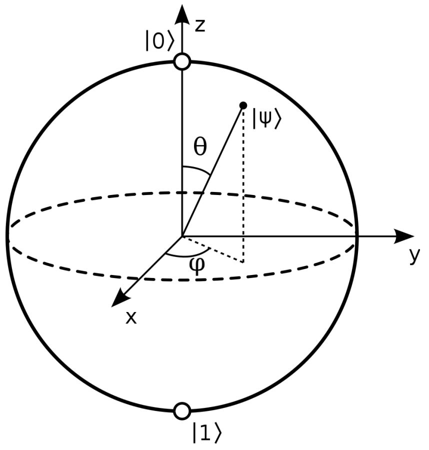
A Quantum Computer does the same… but adds ***superposition*** and ***entanglement***.

The Superposition “Shell Game”



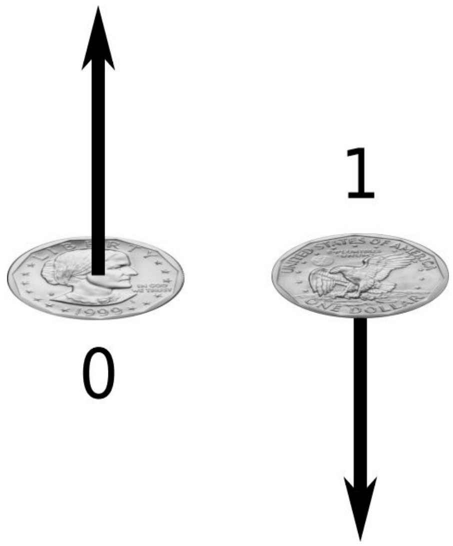
A regular bit has a 100% chance of being in one of the two states “0” or “1”...

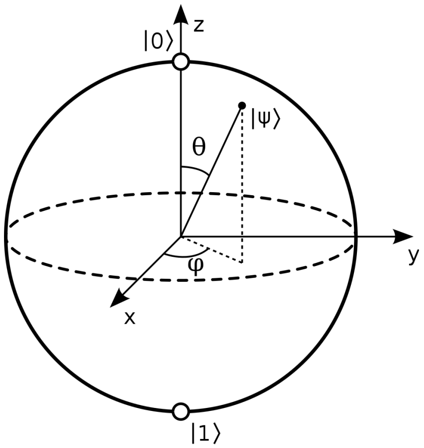




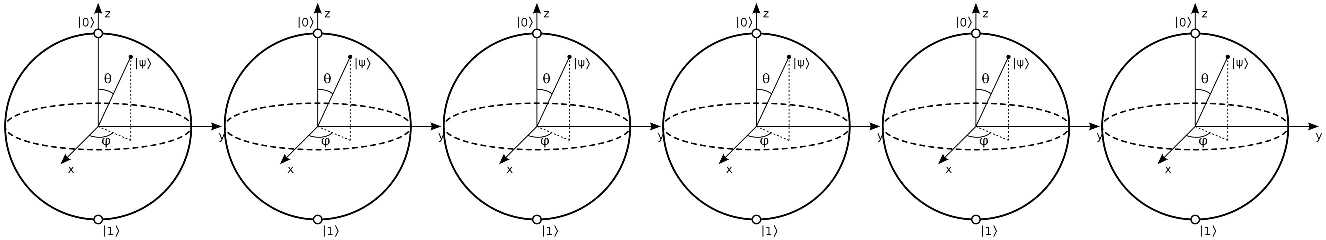
A regular bit has a 100% chance of being in one of the two states “0” or “1”...

...while a quantum bit is in a *superposition* of those states with a *probability* of being 0 or 1 when read.



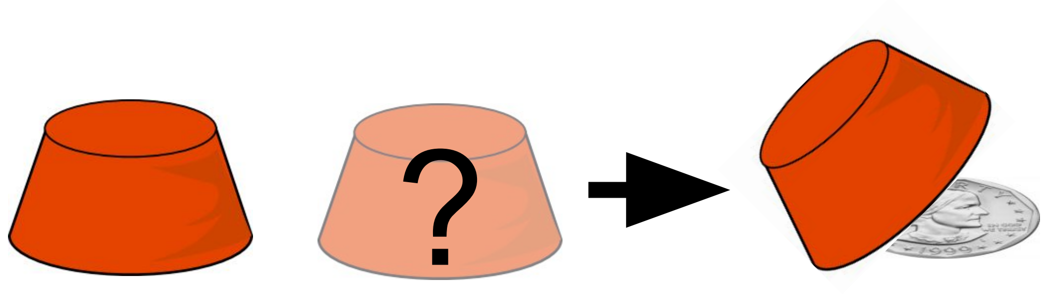


...but if you think a quantum computer is a bunch of individual qubits arranged in nice linear rows...

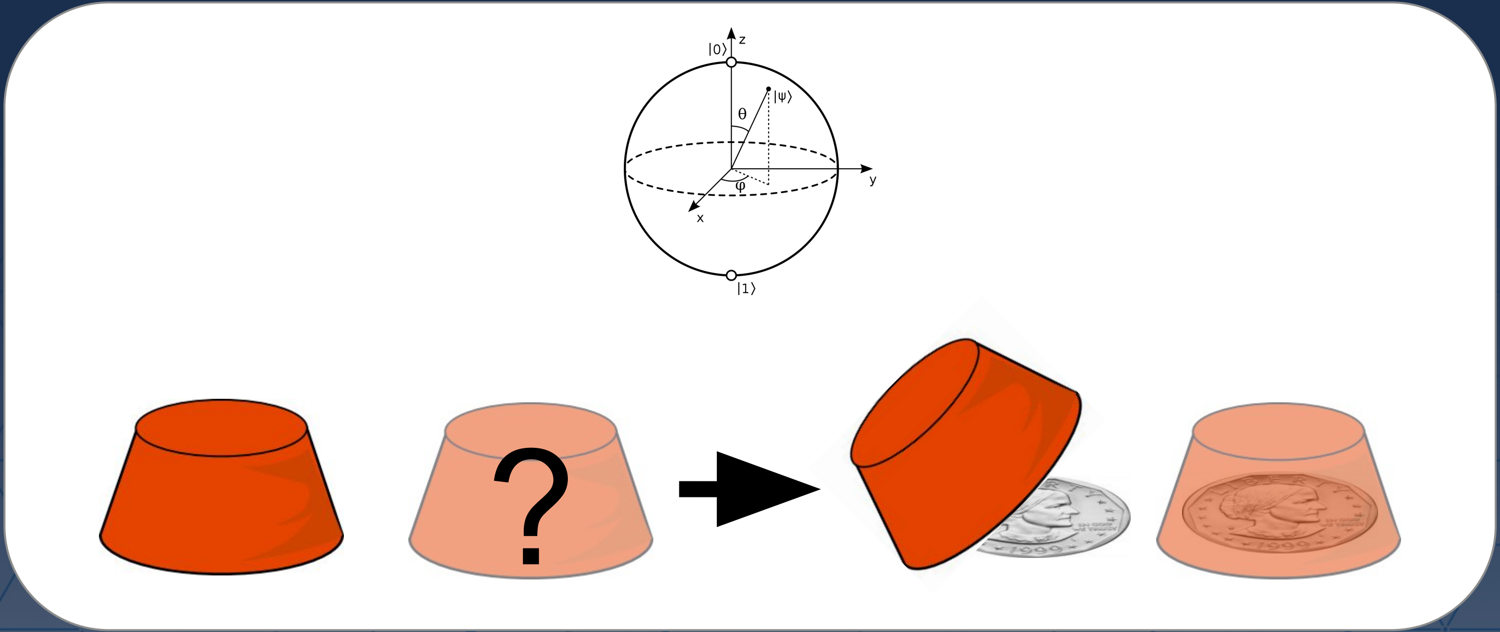


...then you don’t know about the important second part: *entanglement*

Qubits can be *entangled* such that reading the state of one instantaneously fixes the states of all other entangled qubits



The combination of superposition and entanglement lets us *exploit the structure* of a problem so the right answers have a better probability of being picked.



A quantum computer is a *probability machine*

This is worth repeating!

A quantum computer is *not* just a faster classical computer!

It is a *probabilistic* computer that requires *different algorithms* and *different uses*.

The state space of a QC is *big*

- Since a QC is in all of its 2^n states at once, you'd need 2^n double-precision complex numbers to simulate *n* bits

The state space of a QC is *big*

- Since a QC is in all of its 2^n states at once, you'd need 2^n double-precision complex numbers to simulate *n* bits
- ...which means your 16GB laptop could simulate maybe *30 qubits*

The state space of a QC is *big*

- Since a QC is in all of its 2^n states at once, you'd need 2^n double-precision complex numbers to simulate *n* bits

- ...which means your 16GB laptop could simulate maybe *30 qubits*

- ...and a HPC cluster with 3216 nodes of 128GB each (540TB!) could simulate only about *45 qubits*

This leads to scaling

Computer Scientists use “Big-O” notation to talk about a problem’s complexity

This leads to scaling

Computer Scientists use “Big-O” notation to talk about a problem’s complexity

$\mathcal{O}(n)$ Number of claps we’d get if everyone clapped their hands

This leads to scaling

Computer Scientists use "Big-O" notation to talk about a problem's complexity

$\mathcal{O}(n)$	Number of claps we'd get if everyone clapped their hands
$\mathcal{O}(n^2)$	Number of claps we'd get if everyone gave each other a high-five*

*okay, that's really a triangle number, but let's not get too wrapped up

This leads to scaling

Computer Scientists use "Big-O" notation to talk about a problem's complexity

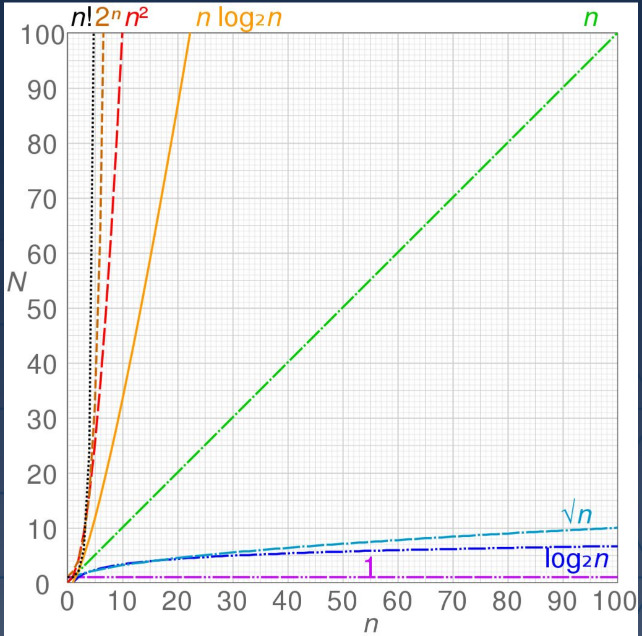
$\mathcal{O}(2^n)$ The analogy sorta breaks down but basically your arms would fall off.

This leads to scaling

Computer Scientists use "Big-O" notation to talk about a problem's complexity

$\mathcal{O}(2^n)$ The analogy sorta breaks down but basically your arms would fall off.

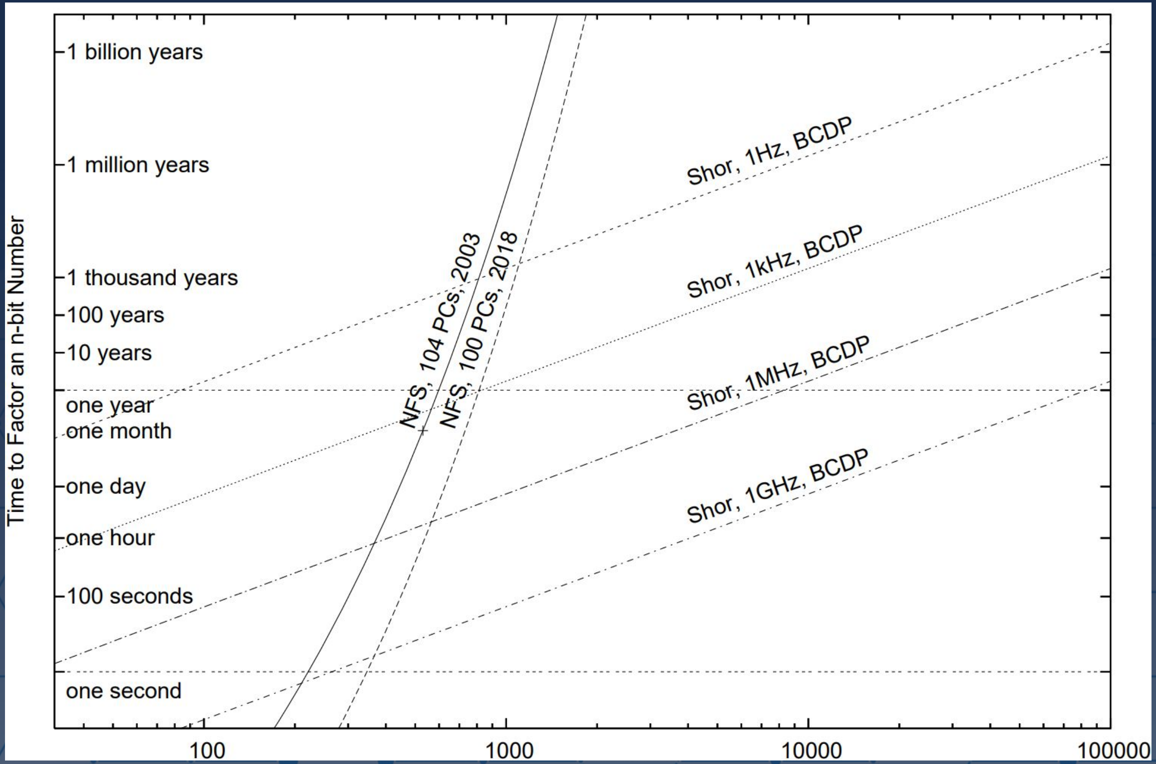
$\mathcal{O}(\log n)$ $\mathcal{O}(\sqrt{n})$ $\mathcal{O}(n!)$ $\mathcal{O}\left(\exp\left(\left(\frac{64}{9}\right)^{\frac{1}{3}}(\log n)^{\frac{1}{3}}(\log\log n)^{\frac{2}{3}}\right)\right)$ $\mathcal{O}(n\log n)$



So when we talk about "quantum advantage", we don't mean
"X times faster"--

We mean "the scaling changes so the bigger the problem, the better the speedup"

...case in point.



Van Meter et al, "Architecture-Dependent Execution Time of Shor's Algorithm", 1 Feb 2008

So... *where* might we see speedups? ...first promising prospects:

Optimization

Quantum Simulation (chemistry)

Machine Learning

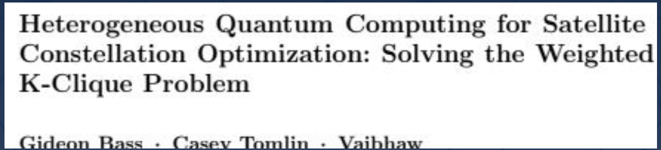
So... *where* might we see speedups? ...first promising prospects:

- Graph Analytics
- Search
- Optimization
- Linear Algebra
- Cryptography
- Quantum Simulation (chemistry)
- Machine Learning

Finally… applications to space

Optimization:

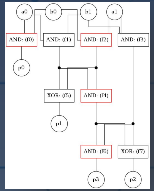
- Constellation design/deployment/tasking

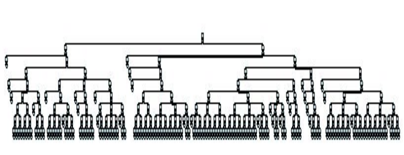


Heterogeneous Quantum Computing for Satellite Constellation Optimization: Solving the Weighted K-Clique Problem

Gideon Bass · Casey Tomlin · Vaibhaw

- Fault tree analysis for design/verification





Finally... applications to space

Chemical/Material Simulation:

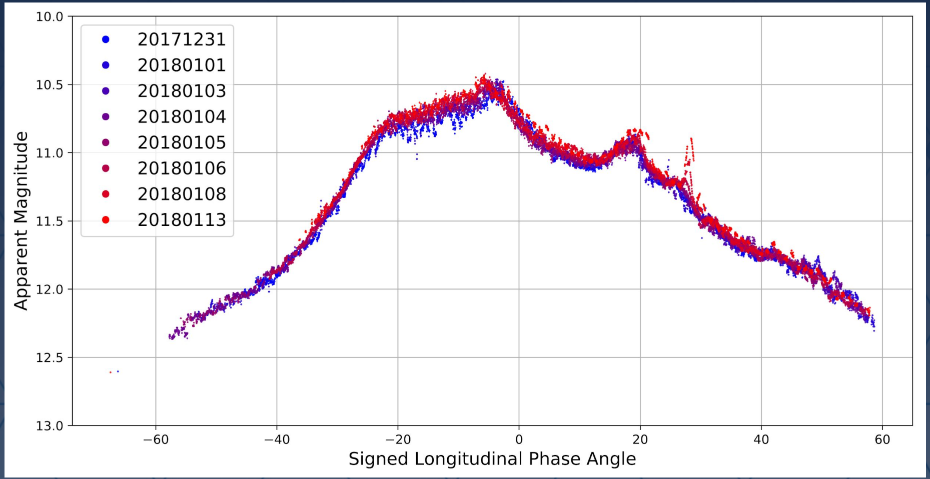
- More on the industrial/materials side, but
  - Better Photovoltaics
  - Better Batteries
  - Greater durability/heat dissipation

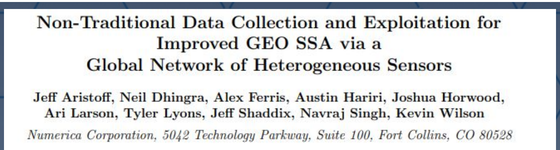
Finally... applications to space

Machine Learning and Data Analytics:

- Graph analyses
- Image/signal recognition

QC Ware Case Study:
applying QML to satellite flare recognition





Non-Traditional Data Collection and Exploitation for Improved GEO SSA via a Global Network of Heterogeneous Sensors

Jeff Aristoff, Neil Dhingra, Alex Ferris, Austin Hariri, Joshua Horwood, Ari Larson, Tyler Lyons, Jeff Shaddix, Navraj Singh, Kevin Wilson

Numerica Corporation, 5042 Technology Parkway, Suite 100, Fort Collins, CO 80528

QC Ware Case Study:
applying QML to satellite flare recognition

It looks promising, but:

- While we may see an exponential speedup for signal classification proper, accuracy and I/O are still problems

QC Ware Case Study:
applying QML to satellite flare recognition

It looks promising, but:

- While we may see an exponential speedup for signal classification proper, accuracy and I/O are still problems
- Current-generation QC hardware is not really capable of large signals for analysis

QC Ware Case Study:
applying QML to satellite flare recognition

It looks promising, but:

- While we may see an exponential speedup for signal classification proper, accuracy and I/O are still problems
- Current-generation QC hardware is not really capable of large signals for analysis
- Finally… actually getting sample data has been surprisingly difficult!

Vic Putz, QC Ware
vic.putz@qcware.com