Scalable Quantum Computing approach at Microsoft

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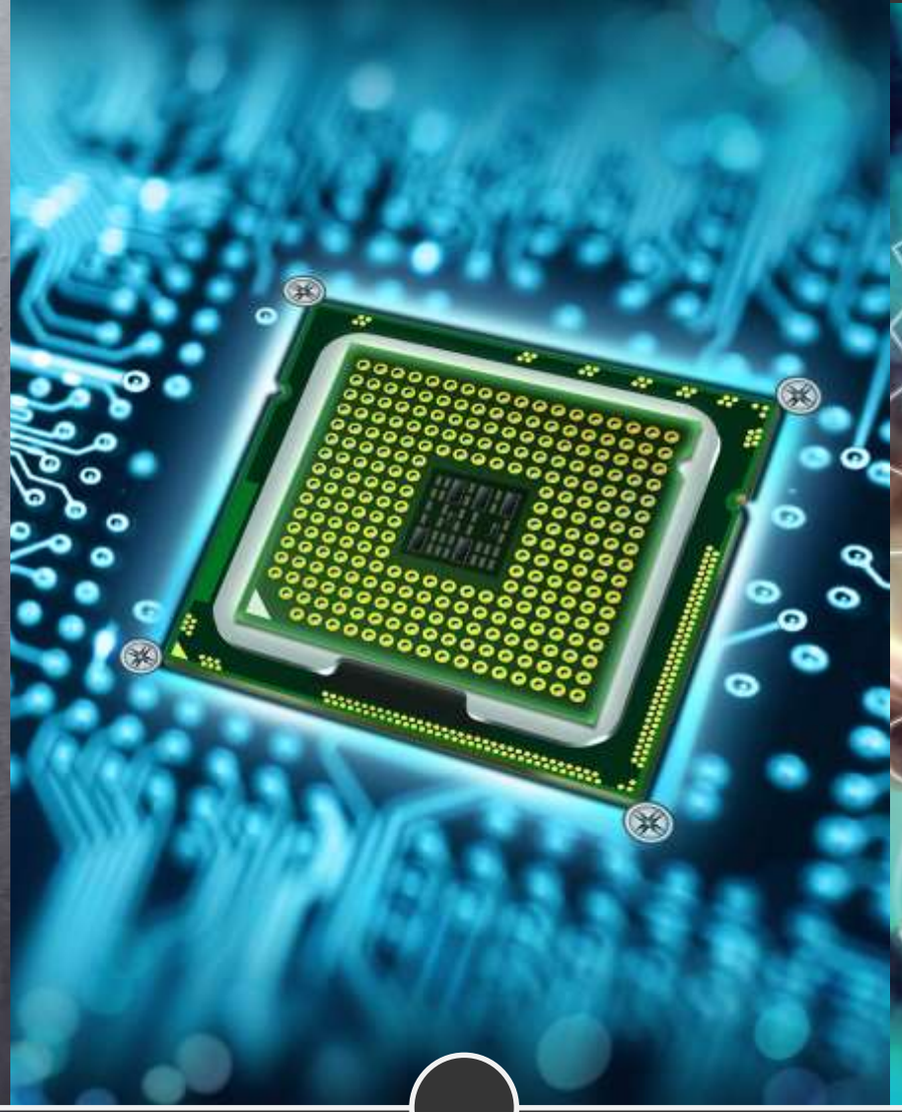
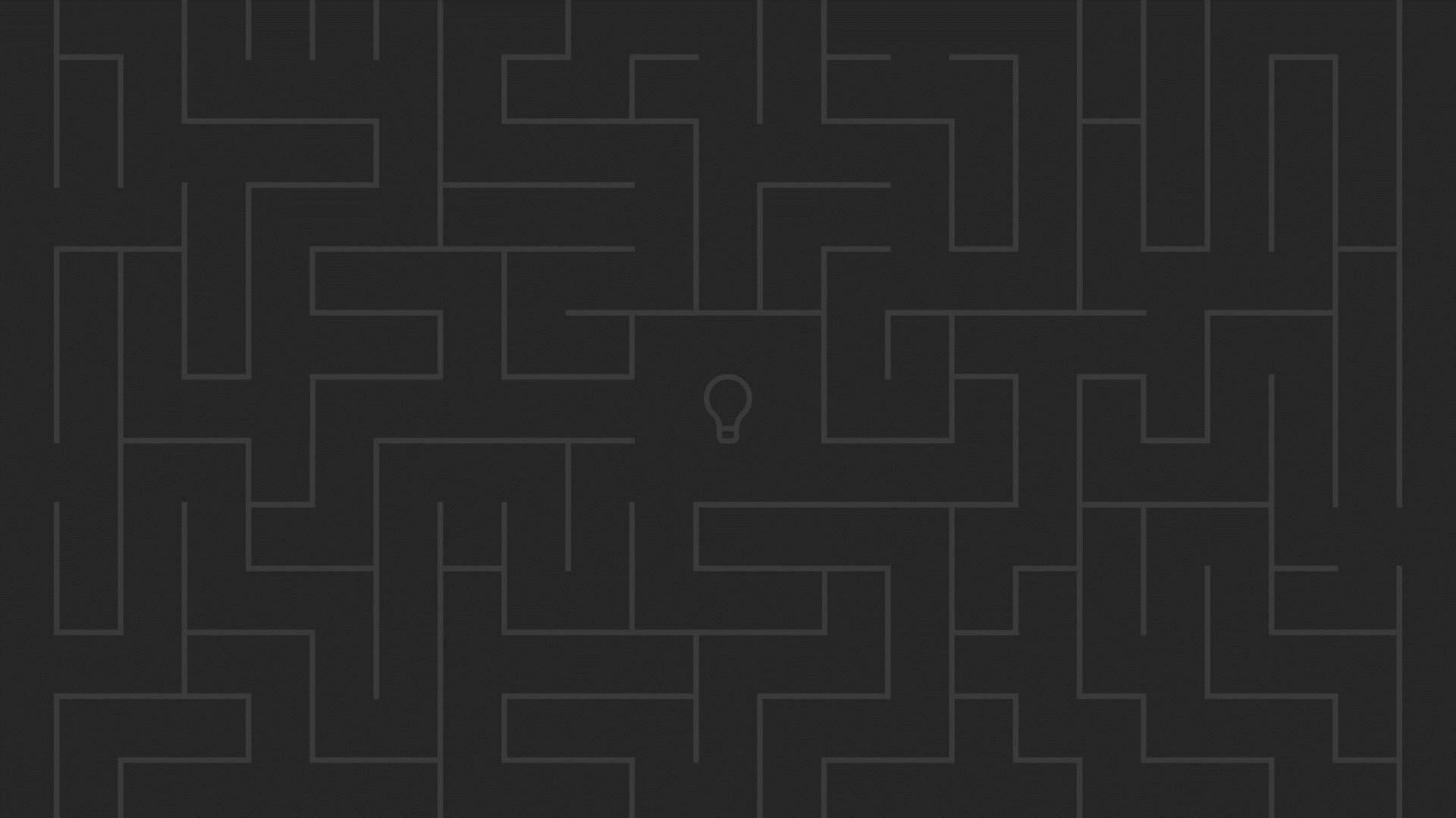
Microsoft

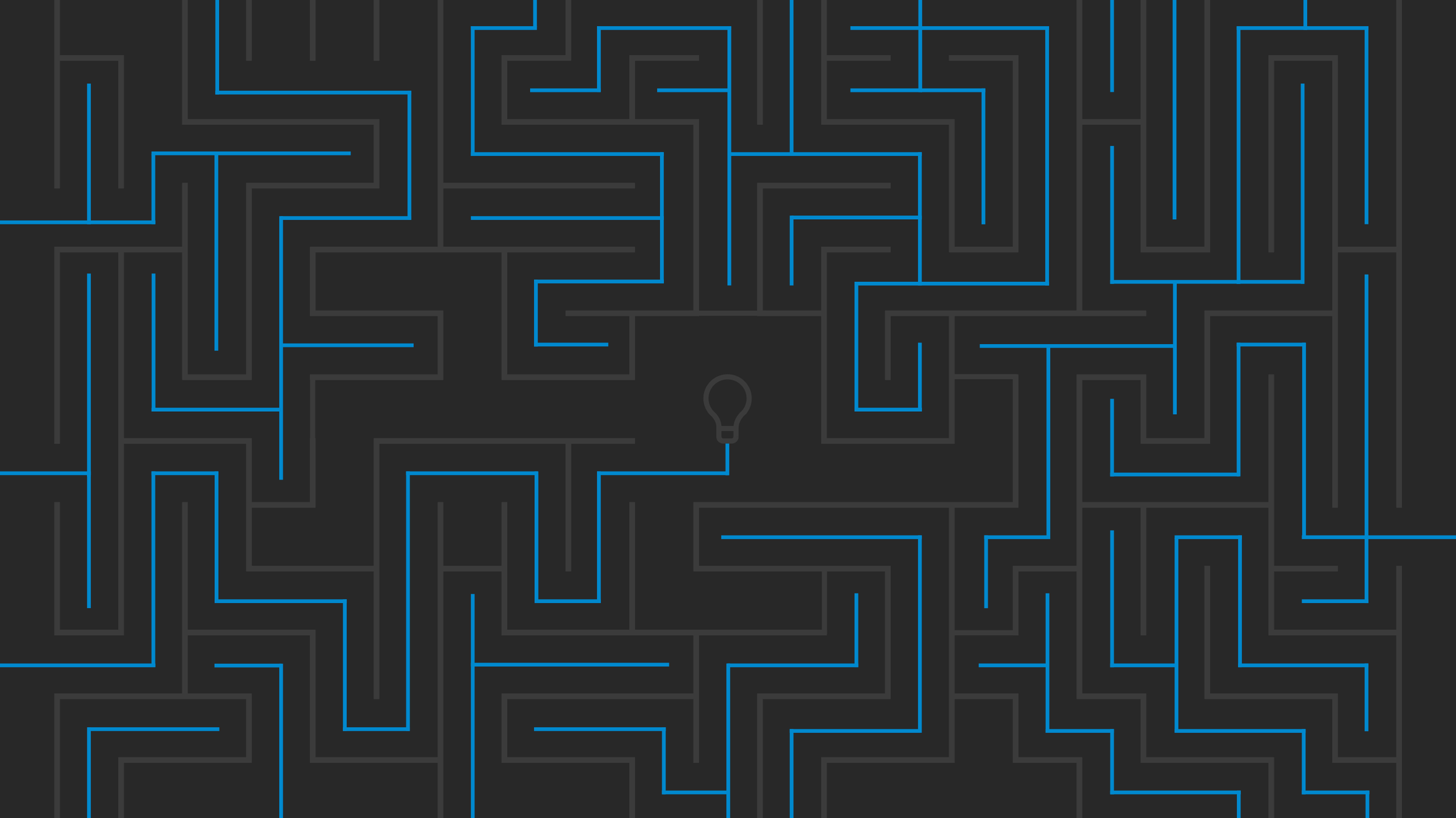


2500
BC

20th
Century

21st
Century



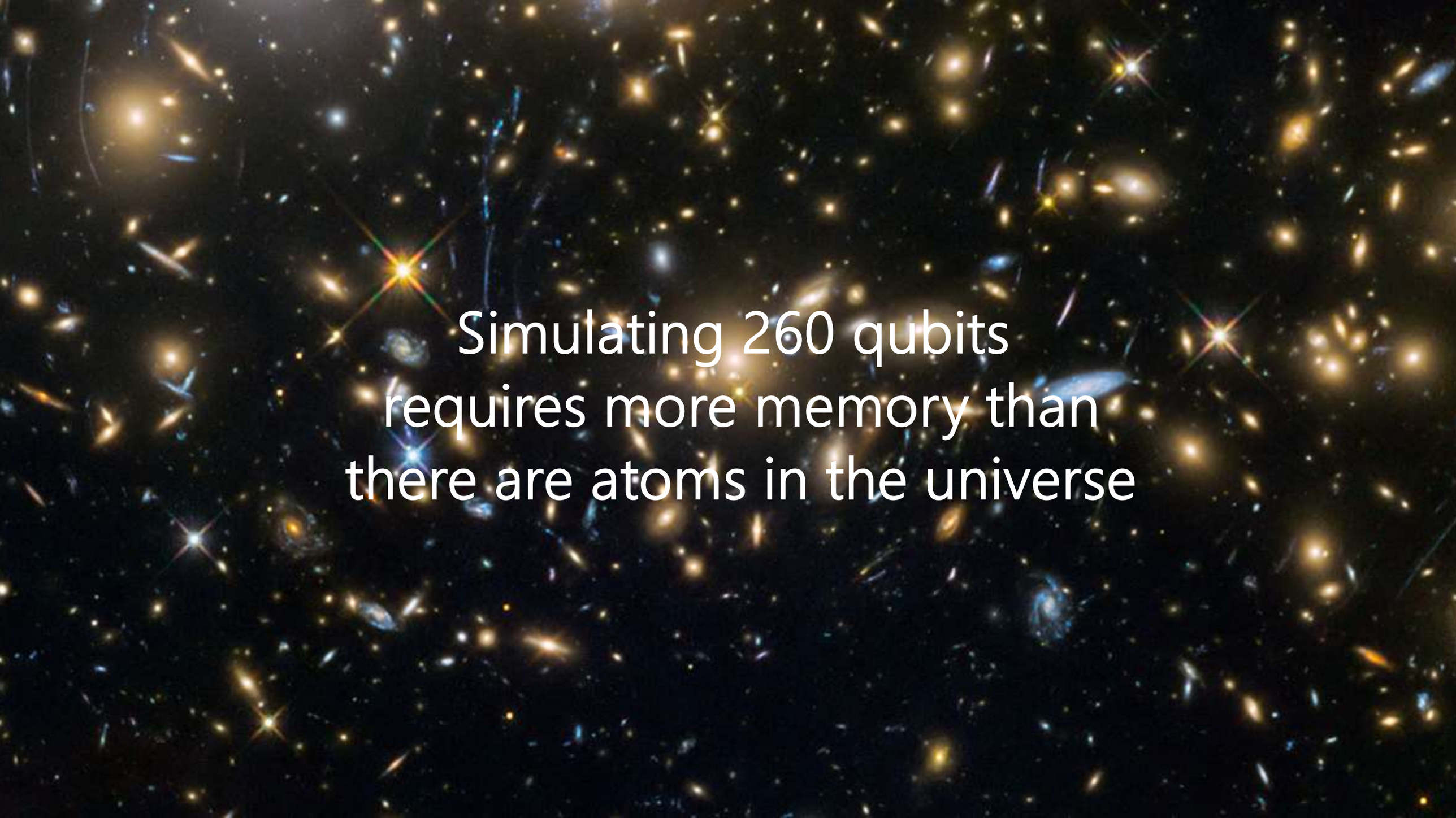


30 qubits → 16 Gb

40 qubits → 16 Tb

50 qubits → 16 Pb

Exponential Scaling


Simulating 260 qubits
requires more memory than
there are atoms in the universe

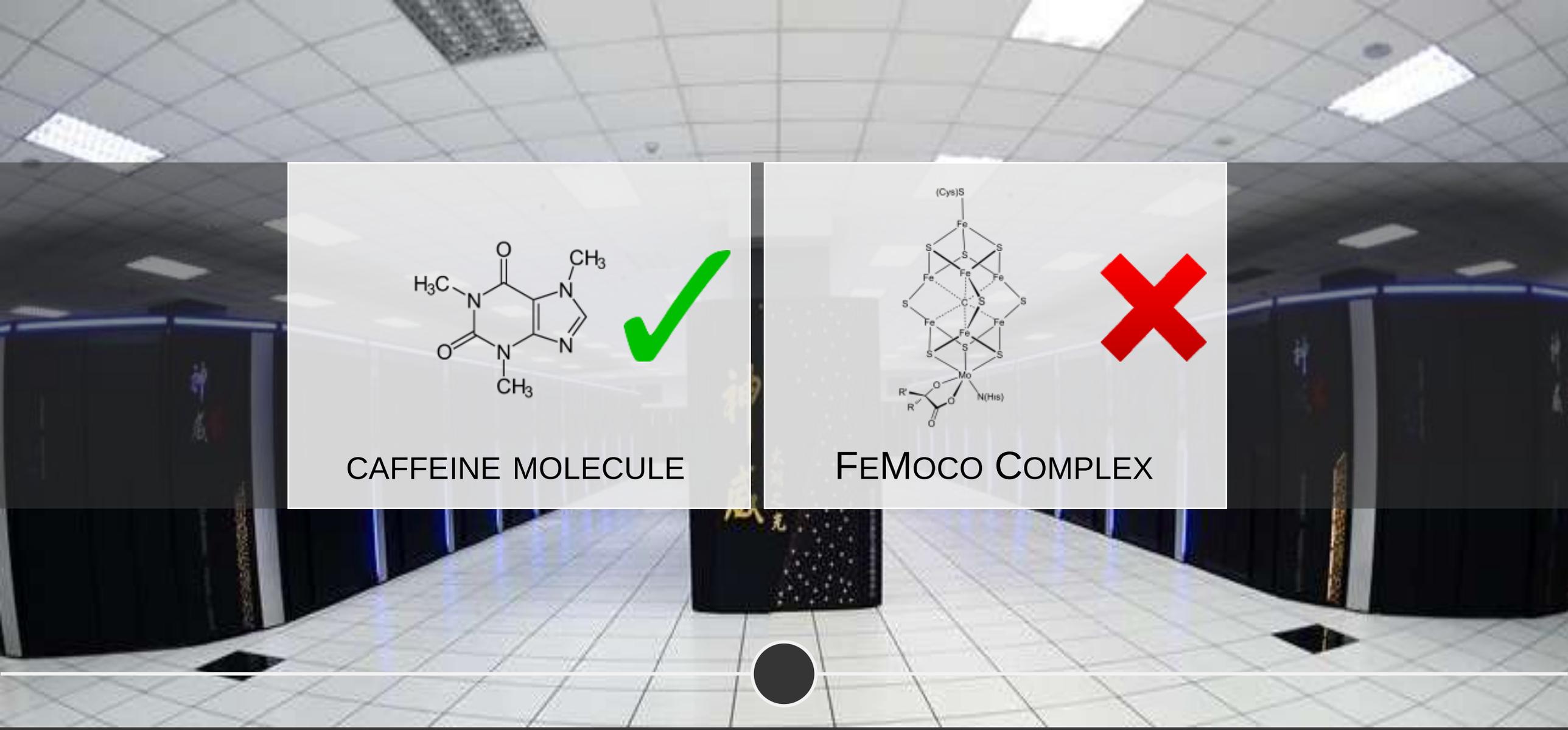
Addressing classically intractable problems

Classical

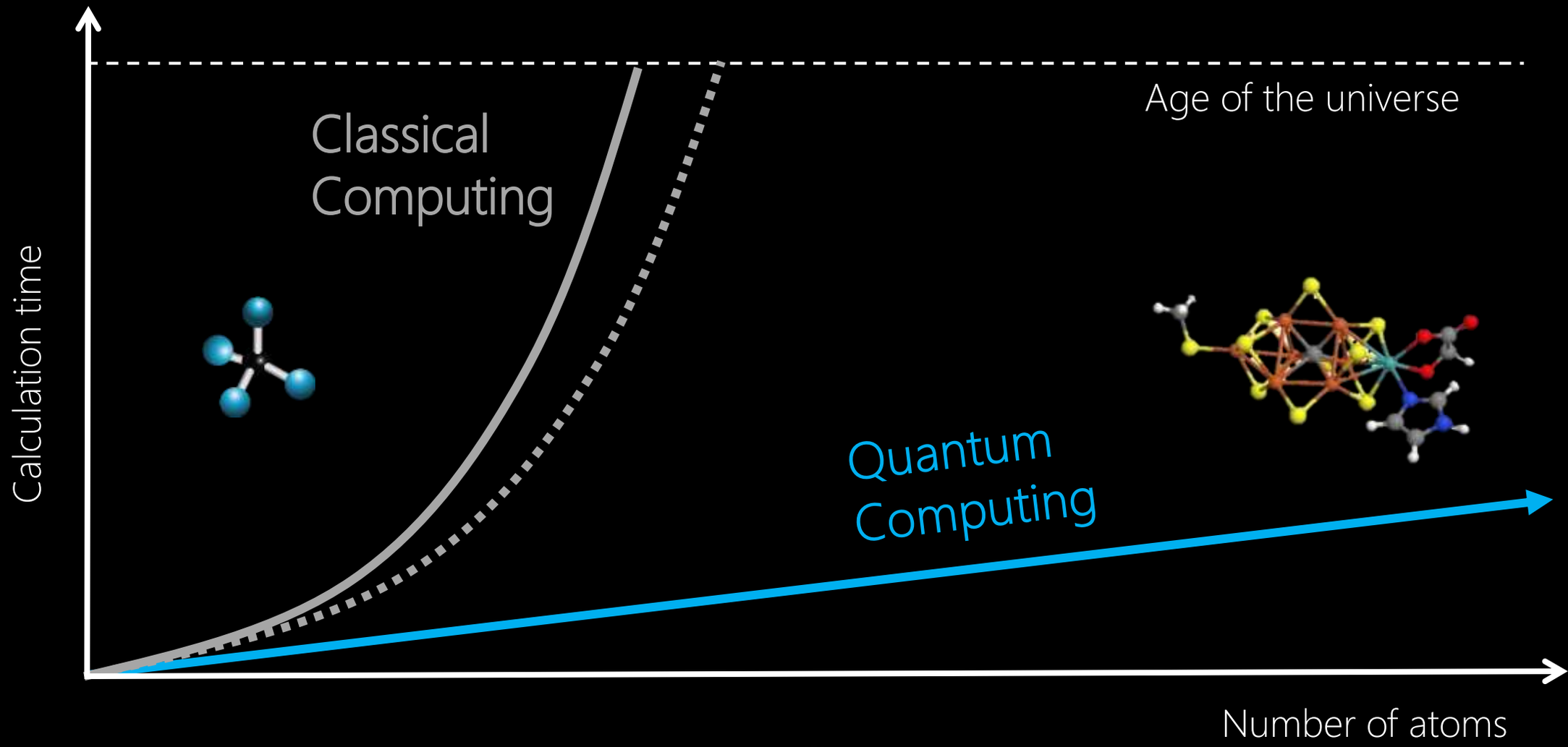
1 billion years

Quantum

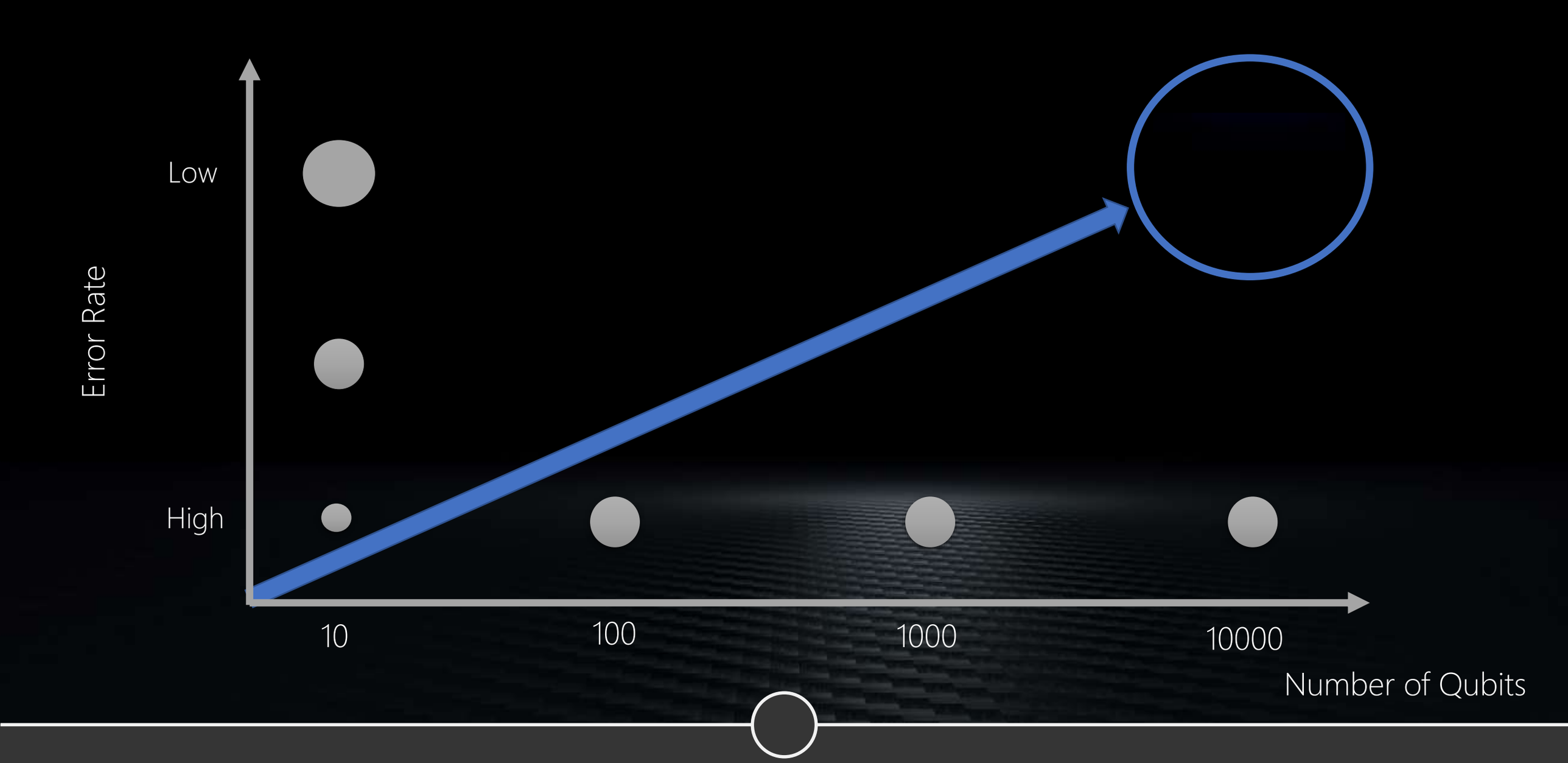
100 seconds



The fastest supercomputer in the world



Addressing classically intractable problems



All qubits are not created equal

Majorana Fermions

Predicted by Ettore Majorana in 1937

Inspiration

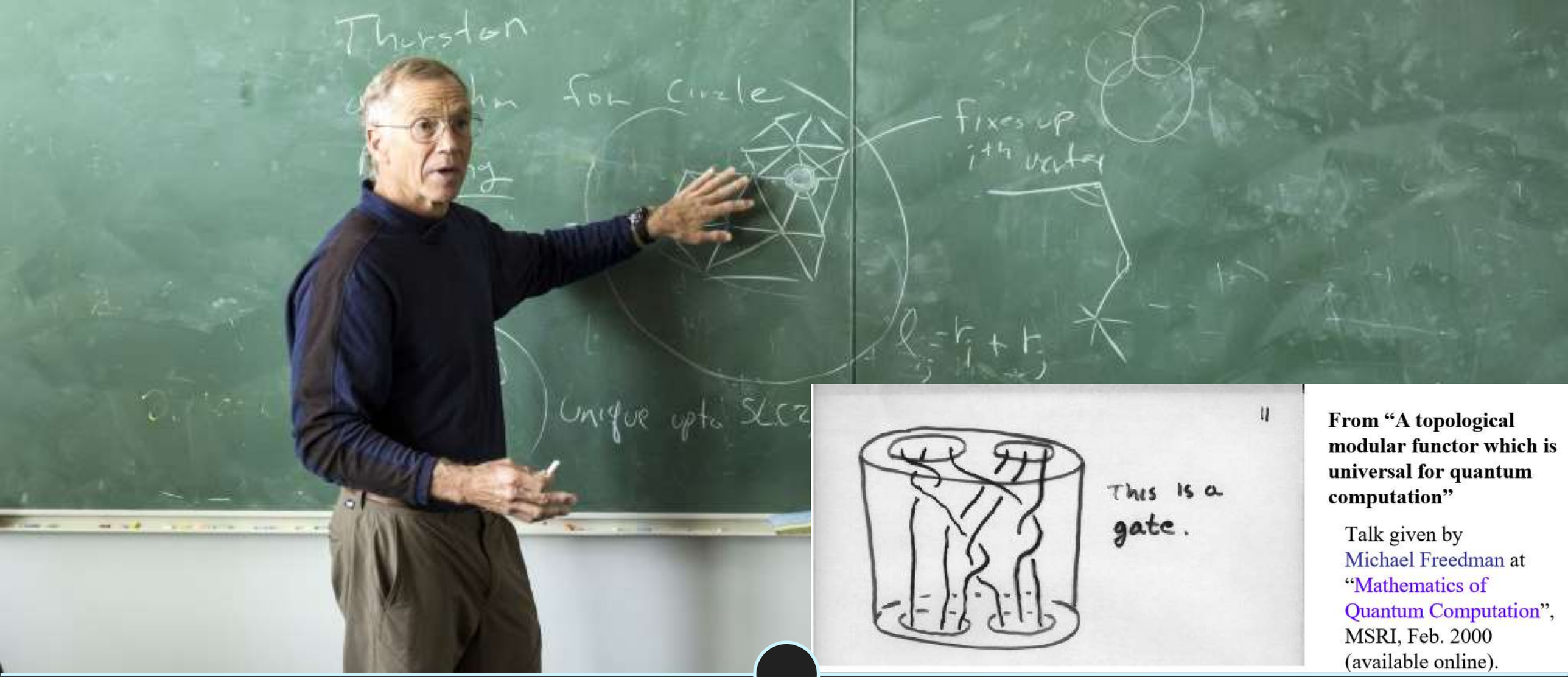
Fault-tolerant quantum computation by anyons

A. Yu. Kitaev

(Submitted on 9 Jul 1997)

A two-dimensional quantum system with anyonic excitations can be considered as a quantum computer. Unitary transformations can be performed by moving the excitations around each other. Measurements can be performed by joining excitations in pairs and observing the result of fusion. Such computation is fault-tolerant by its physical nature.

Comments:	27 pages, Latex2e, uses amssymb.sty, 13 Postscript figures
Subjects:	**Quantum Physics (quant-ph)**; Mesoscale and Nanoscale Physics (cond-mat.mes-hall); High Energy Physics - Theory (hep-th)
Journal reference:	Annals Phys. 303 (2003) 2-30
DOI:	10.1016/S0003-4916(02)00018-0
Cite as:	**arXiv:quant-ph/9707021** (or **arXiv:quant-ph/9707021v1** for this version)



From "A topological modular functor which is universal for quantum computation"

Talk given by Michael Freedman at "Mathematics of Quantum Computation", MSRI, Feb. 2000 (available online).

2000

STATION

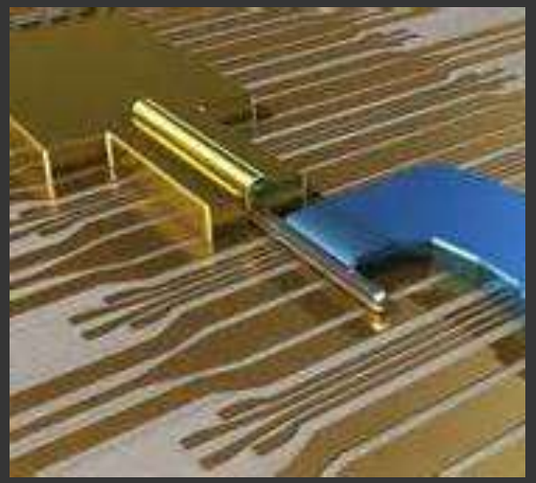
2006

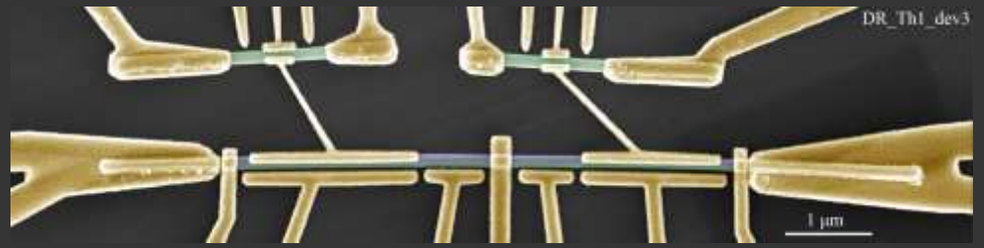
MAJORANA PARTICLE GLIMPSED IN LAB.

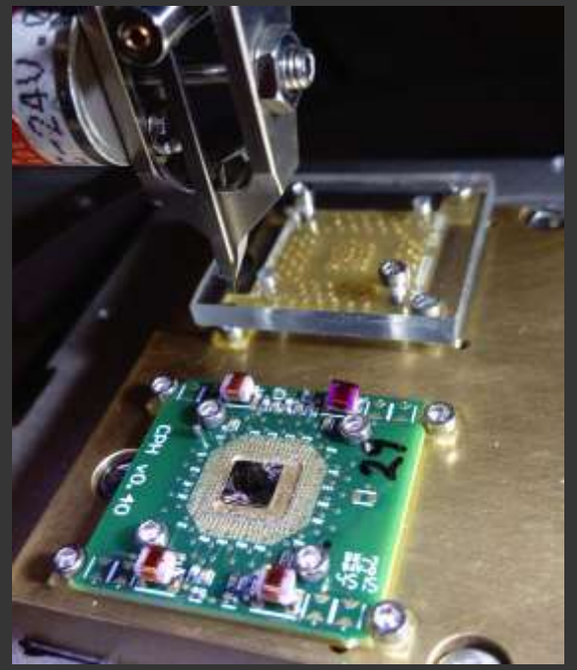
BBC NEWS

2012

Develop and deploy a scalable, commercial quantum system to solve today's unsolvable problems





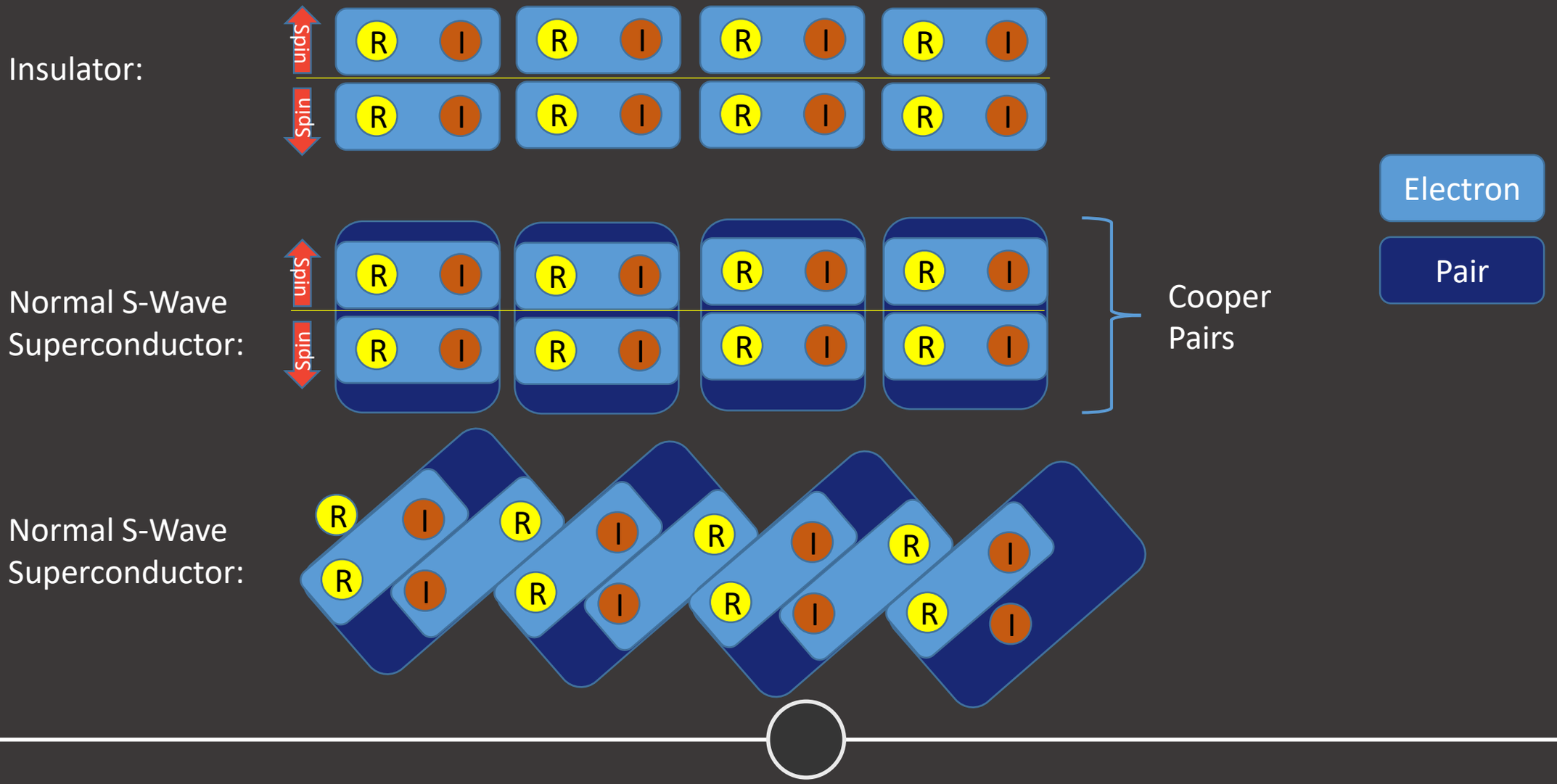


2018

Electron Spin

Electron Fractionalization

Superposition



Electron Fractionalization

Superposition

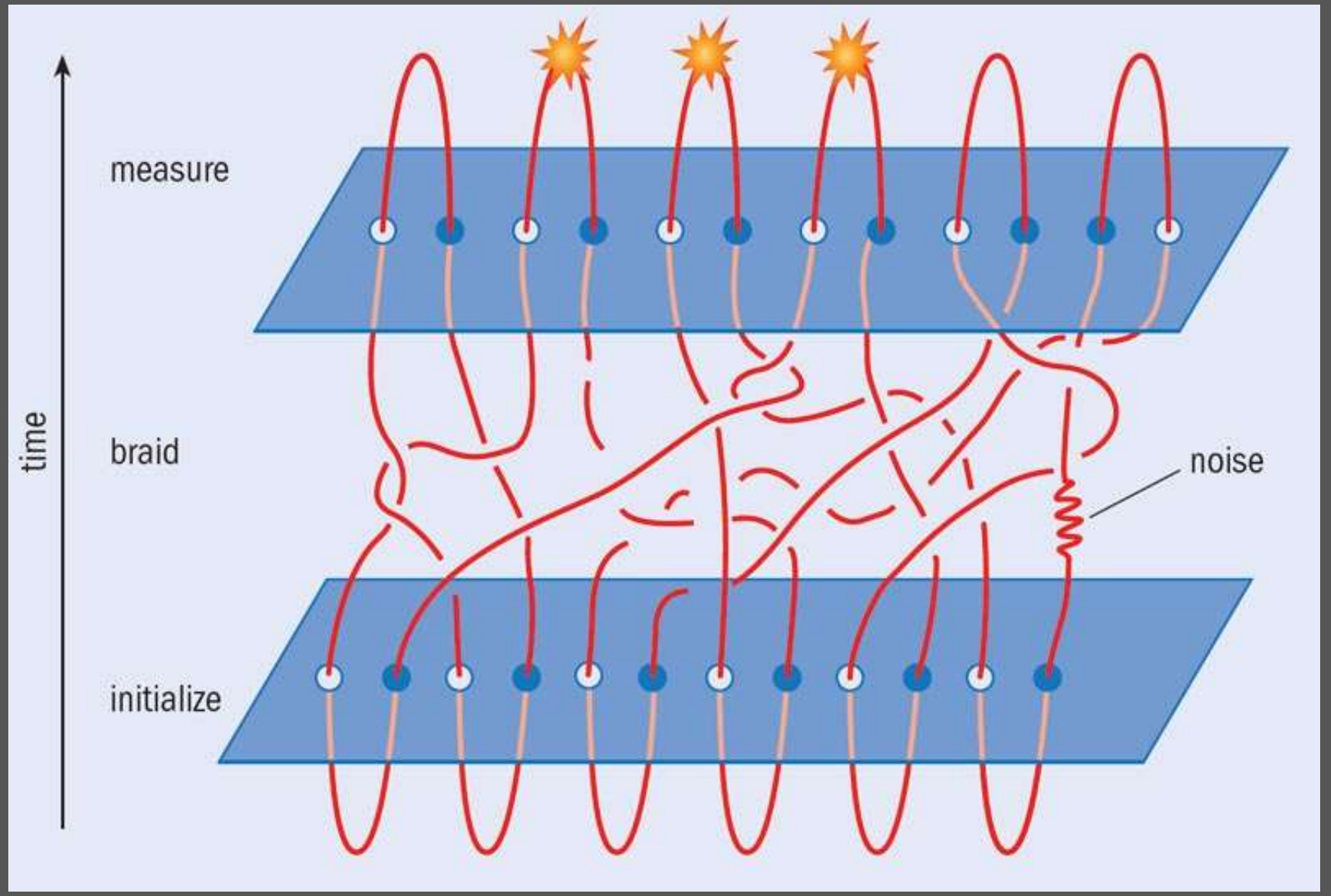
Inca Quipu

Qubit Technologies

Realizations	Lifetimes	Gate Speed	ECC cost
Topological (Majorana)	1 minute	Nanoseconds	$\mathbf{10^1}$
Flux Qubit	$/\ 10^{10}$	same	$10^3 - 10^4$
Charge Qubit	$/\ 10^{10}$	same	$10^3 - 10^4$
Transmon	$/\ 10^{7}$	same	$10^3 - 10^4$
Ion Trap	$/\ 10^{2}$	10^3 slower	$10^3 - 10^4$

- ECC is extremely painful (no “quantum refresh” like DRAM)
- Many can be fabricated with variations on standard semiconductor techniques

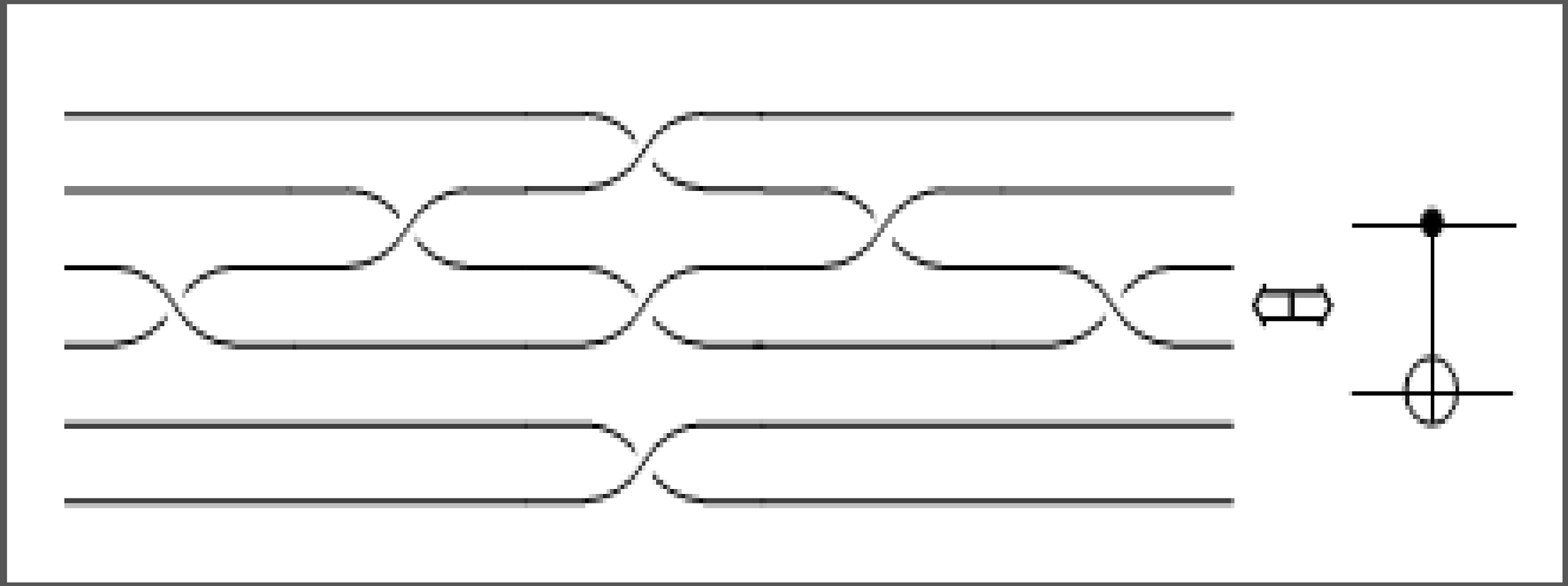
Braiding



Source: https://physicsworld.com/a/quantum-computing-with-a-twist/

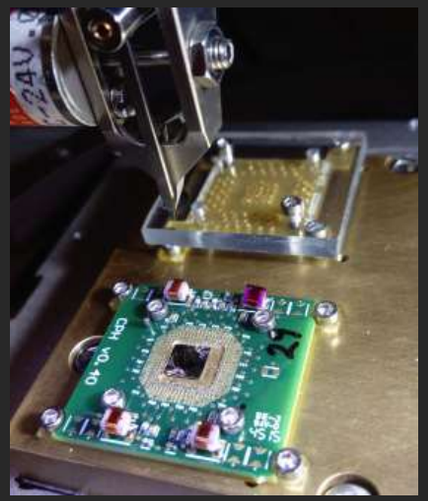
The example of the CNOT quantum gate

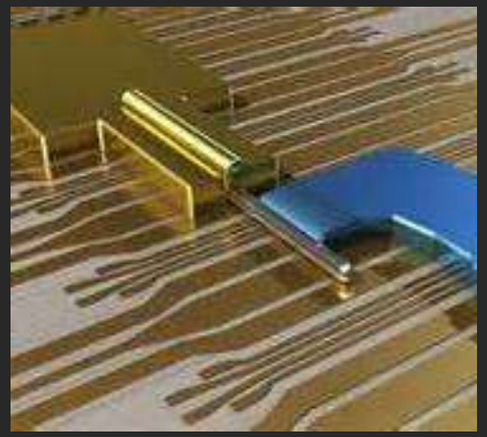
A CNOT Gate is a quantum reversible equivalent to a XOR gate



Richard Feynman:
"Shut up & calculate!"

Quantum 2.0:
"Shut up & engineer!"





300K	80.33F	← Room temp	
100	-279.67	← DRAM	
Nitrogen →			
30	-405.67		
10	-441.67		
Helium →			
		← Cryogenic Computer	
3	-454.27		
Deep Space →			
1	-457.87		
0.3	-459.13		
0.1	-459.49		
0.03	-459.65		
Quantum Computer →		← Quantum World	
0.01K	-459.65F		

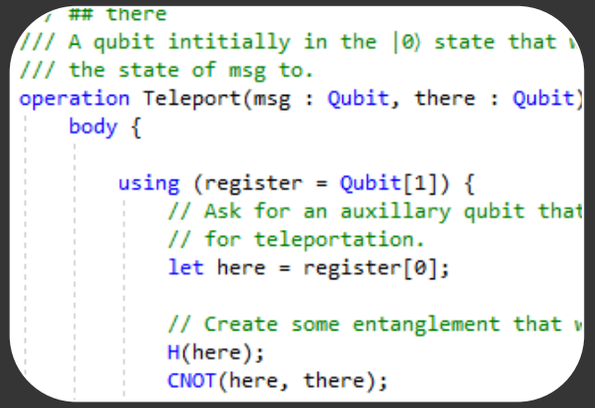
APPLICATIONS + SW

CRYOGENIC COMPUTER CONTROL SW

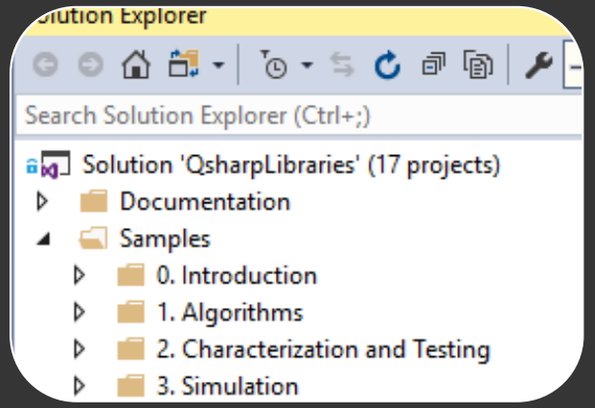
QUANTUM COMPUTER

Introducing the

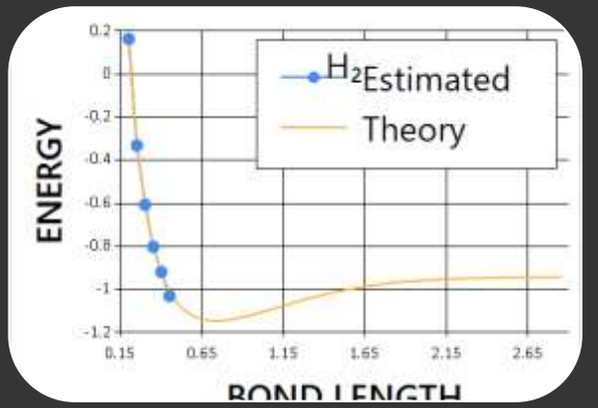
Microsoft Quantum Development Kit



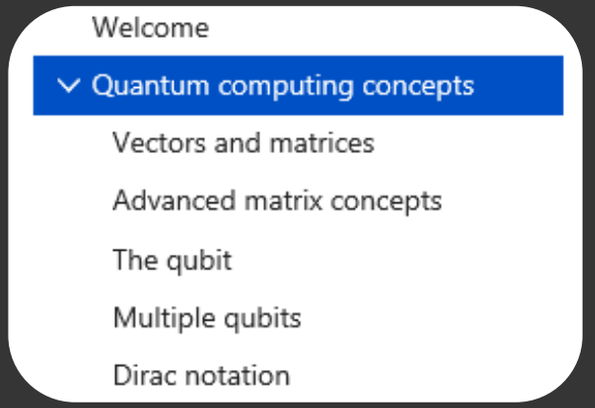
Quantum programming language



Visual Studio integration and debugging



Local and cloud quantum simulation



Extensive libraries, samples, and documentation

Quantum Development Kit

https://www.microsoft.com/en-us/quantum/development-kit


HOW'S YOUR QUANTUM COMPUTER PROTOTYPE COMING ALONG?
GREAT!
Dilbert.com DilbertCartoonist@gmail.com
THE PROJECT EXISTS IN A SIMULTANEOUS STATE OF BEING BOTH TOTALLY SUCCESSFUL AND NOT EVEN STARTED.
4-17-12 ©2012 Scott Adams, Inc./Dist. by Universal Uclick
CAN I OBSERVE IT?
THAT'S A TRICKY QUESTION.

End

Photos courtesy of: Professor Charlie Marcus