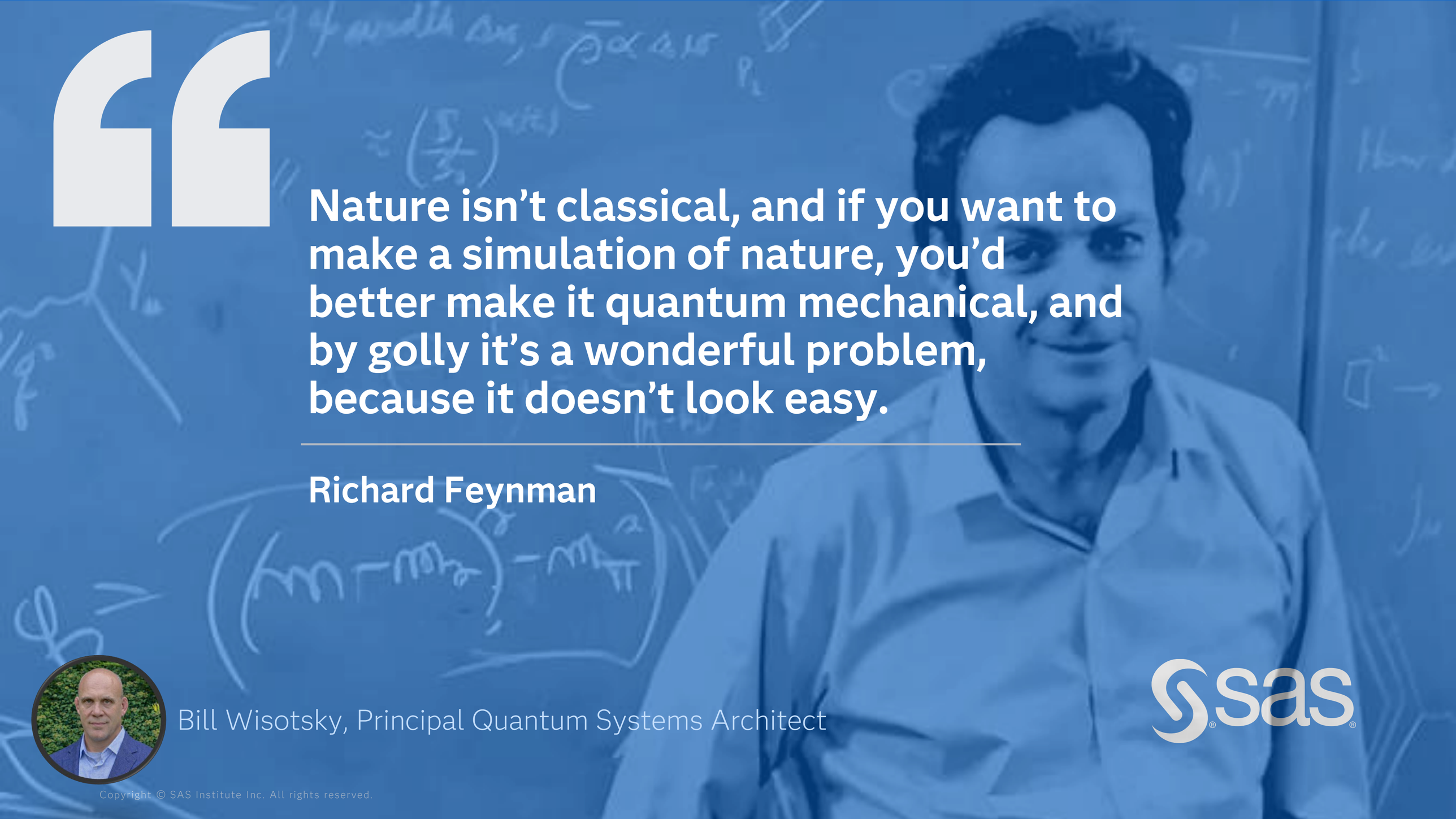


Nature isn’t classical, and if you want to make a simulation of nature, you’d better make it quantum mechanical, and by golly it’s a wonderful problem, because it doesn’t look easy.

Richard Feynman

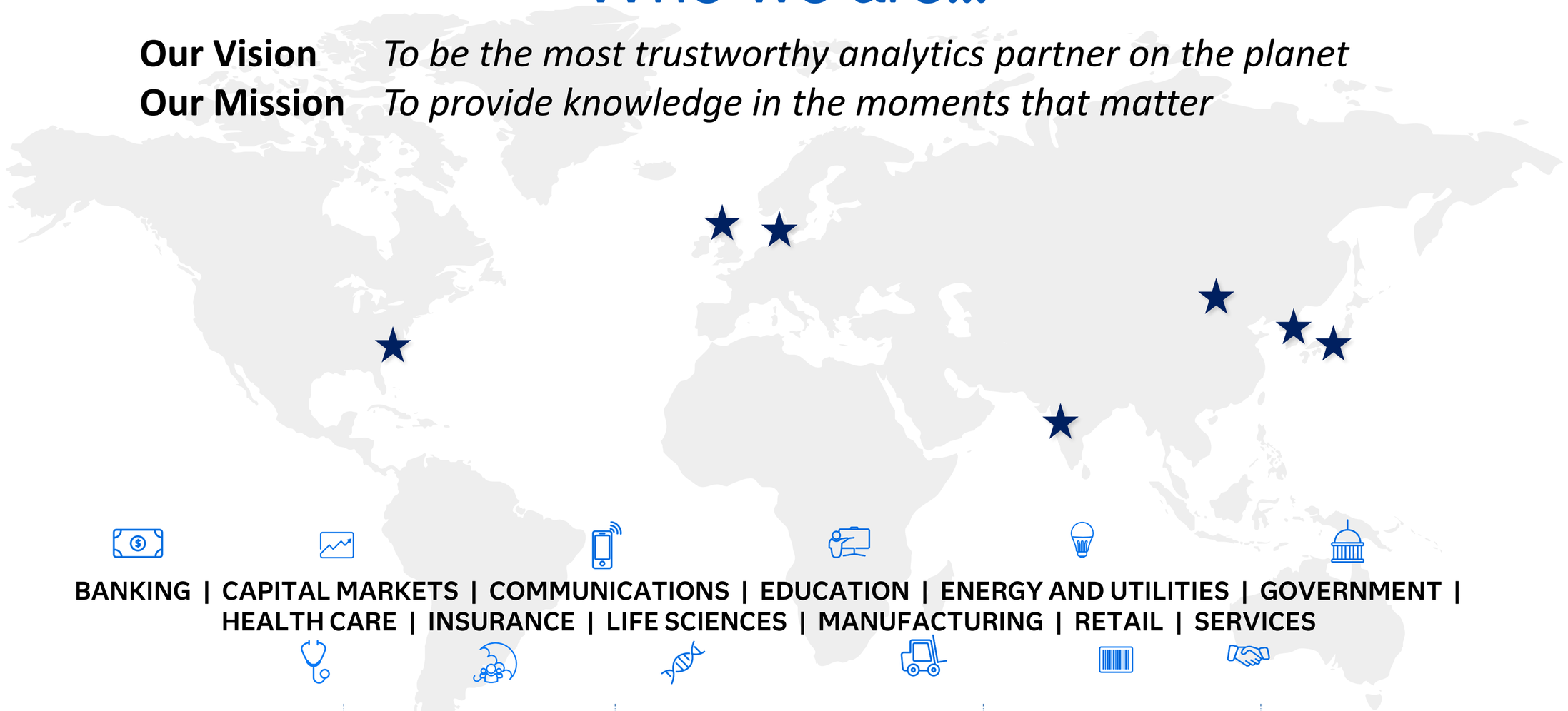
Bill Wisotsky, Principal Quantum Systems Architect

sas

Who we are...

Our Vision *To be the most trustworthy analytics partner on the planet*

Our Mission *To provide knowledge in the moments that matter*



BANKING | CAPITAL MARKETS | COMMUNICATIONS | EDUCATION | ENERGY AND UTILITIES | GOVERNMENT | HEALTH CARE | INSURANCE | LIFE SCIENCES | MANUFACTURING | RETAIL | SERVICES

12,000+	150+	83,000+	1976	96%
Global Employees	Countries with Customers	Customer Sites	Year Established	Annual Customer Retention

Image Generated by MSFT Copilot, 2024

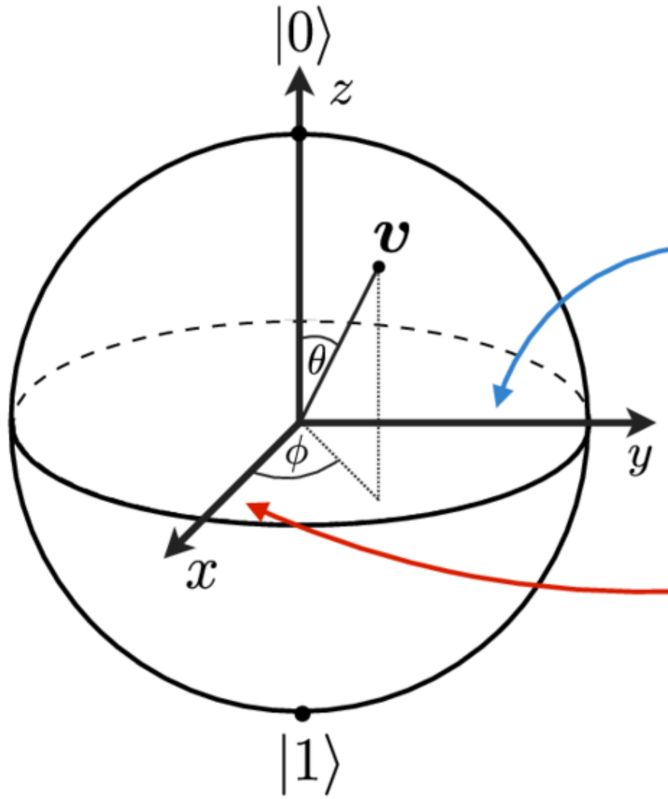
We Are Here!

What is Quantum Computing ?

> If you aren’t confused by quantum mechanics, you haven’t really understood it.

Neils Bohr

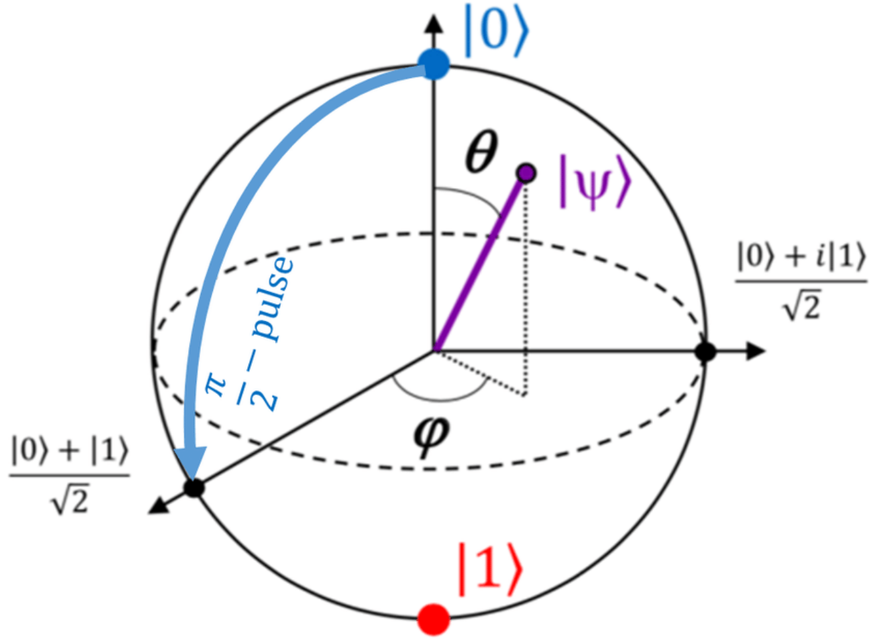
The Bloch Sphere



Pole states:

$$|i+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + i|1\rangle)$$
$$|i-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - i|1\rangle)$$

$$|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$
$$|-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$$



$$|\psi\rangle = cos\frac{\theta}{2}|0\rangle + e^{i\varphi}sin\frac{\theta}{2}|1\rangle$$

A **Quantum State** is a **combination** of **three** different **axes.**

Classic bits versus qubits

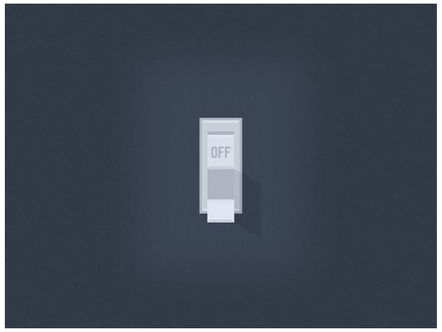
The qubit state can be both 0 and 1 until measured

Classical bit

0

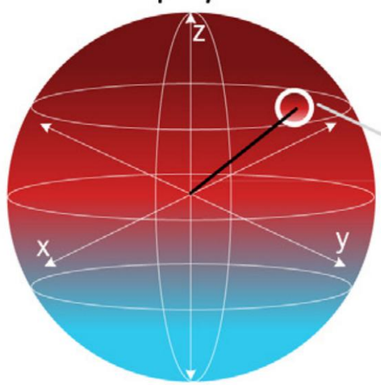
or

1



Quantum bit (Qubit)

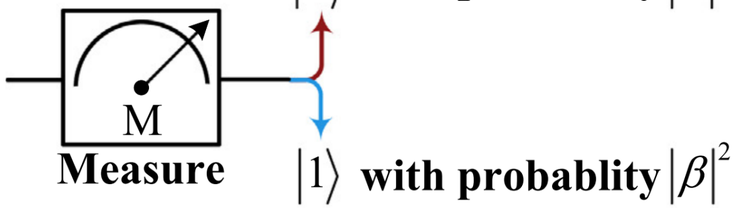
$|0\rangle$



$|1\rangle$

Superposition

$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$

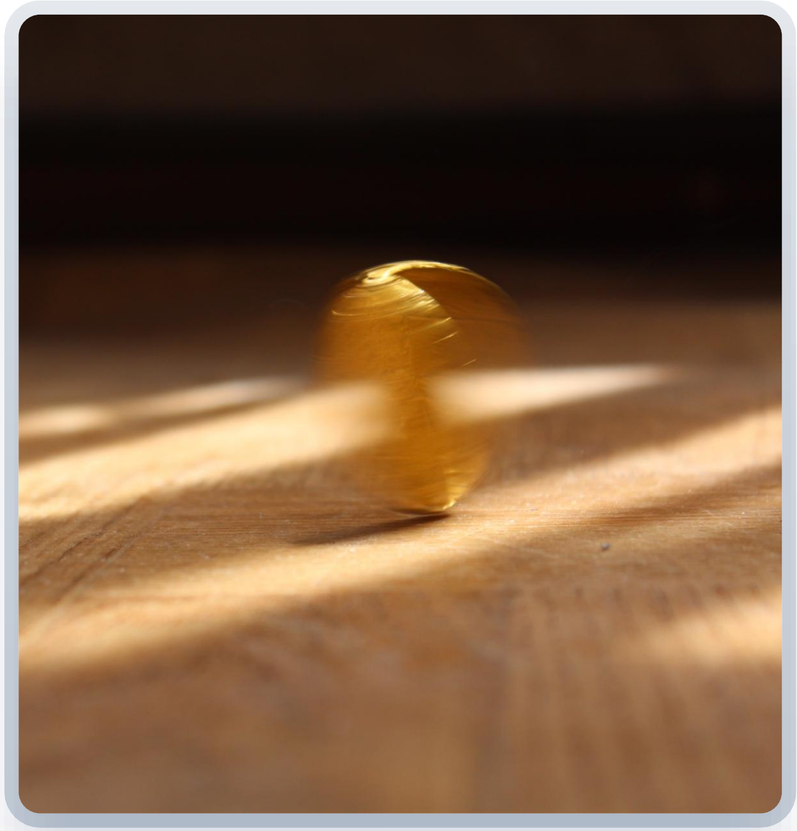


$|0\rangle$ **with probablity** $|\alpha|^2$

$|1\rangle$ **with probablity** $|\beta|^2$

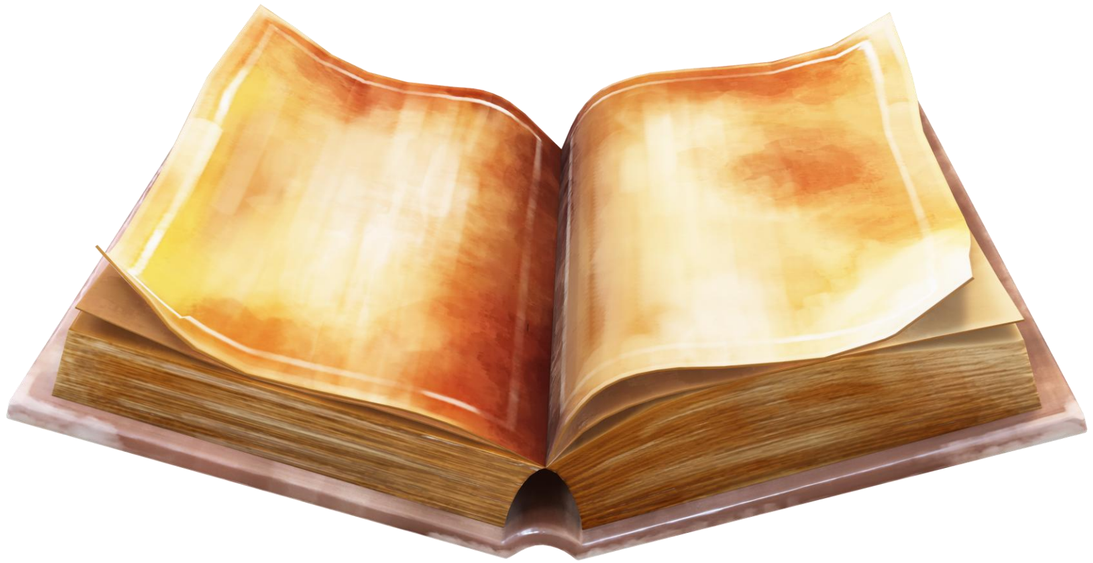
Superposition

Number of Qubits	Simultaneous Computation States ($2^{n\text{-qubits}}$)
1	2 (1 and 0)
2	4 (00 01 10 11)
3	8 (000 001 010 100 101 110 111 011)



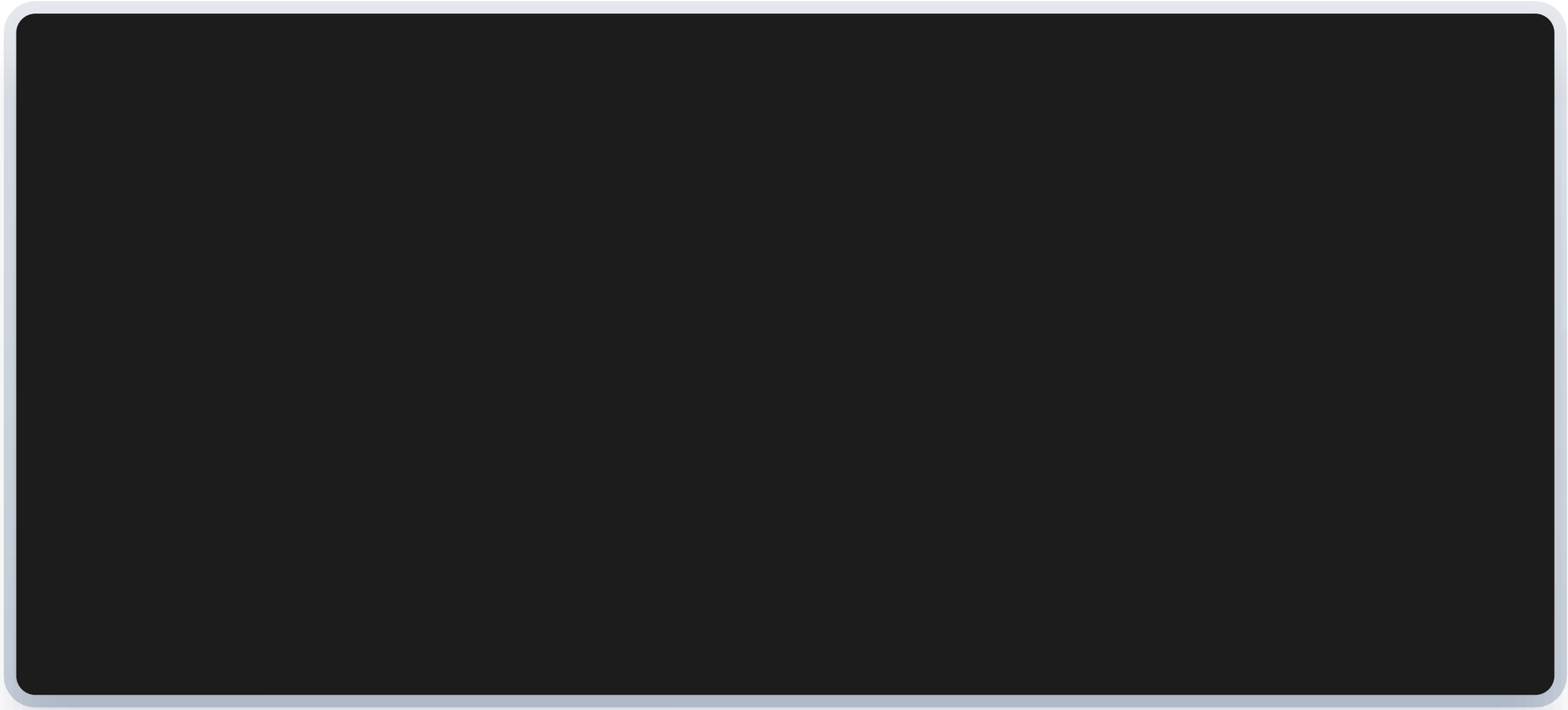
A qubit **isn't just 0 or 1—it's both**.
And, with **each qubit, the state space doubles.**

Quantum Entanglement

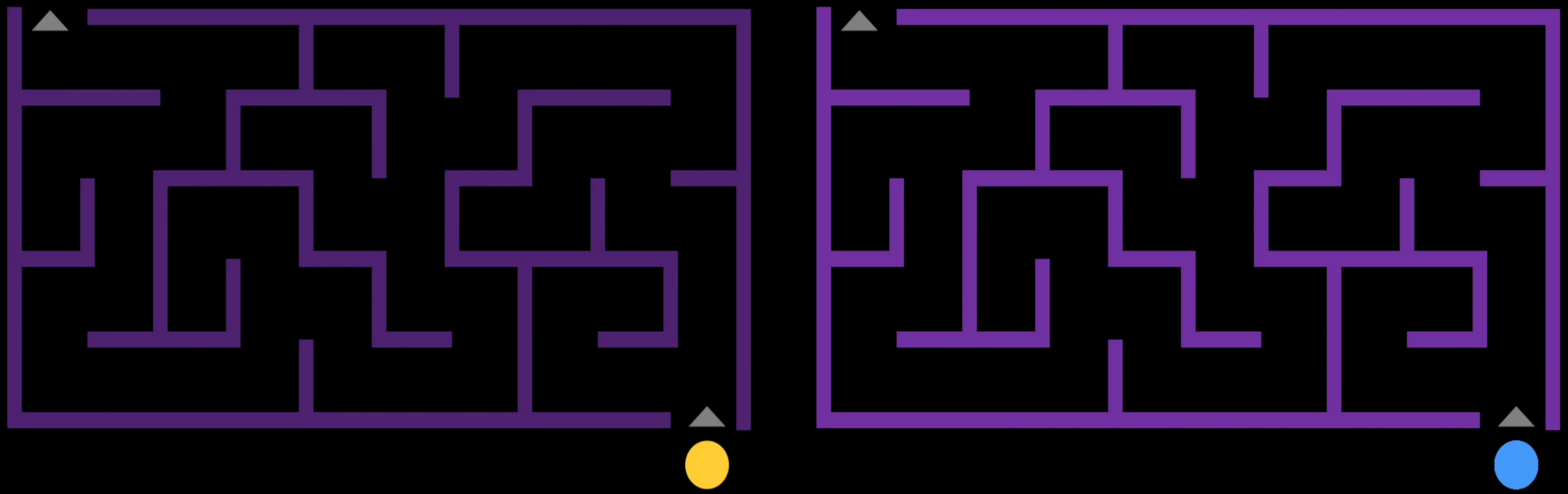


Quantum particles can become **entangled**, **remaining linked** no matter how far apart they are "**Spooky action at a distance**." –Albert Einstein

Quantum Tunneling

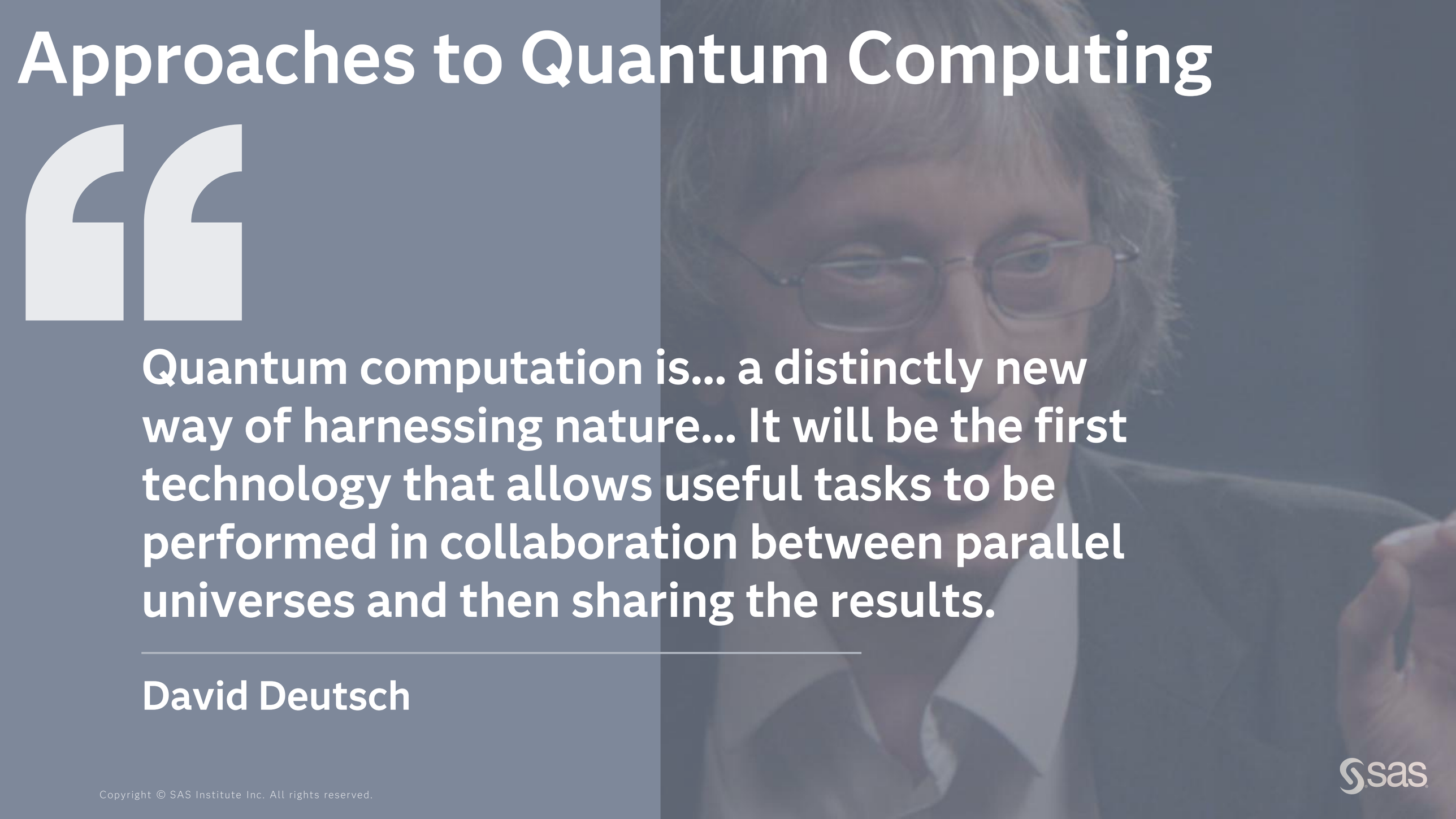


In the quantum world, **barriers aren’t walls—they’re probabilities**



Quantum Computing turns a maze from a **sequence of guesses**
into a **single, parallel exploration**

Approaches to Quantum Computing



> Quantum computation is... a distinctly new way of harnessing nature... It will be the first technology that allows useful tasks to be performed in collaboration between parallel universes and then sharing the results.

David Deutsch

Quantum Annealing

- Combinatorial optimization problems
- Use of Adiabatic Method
- Can handle large problems
- Commercial uses today

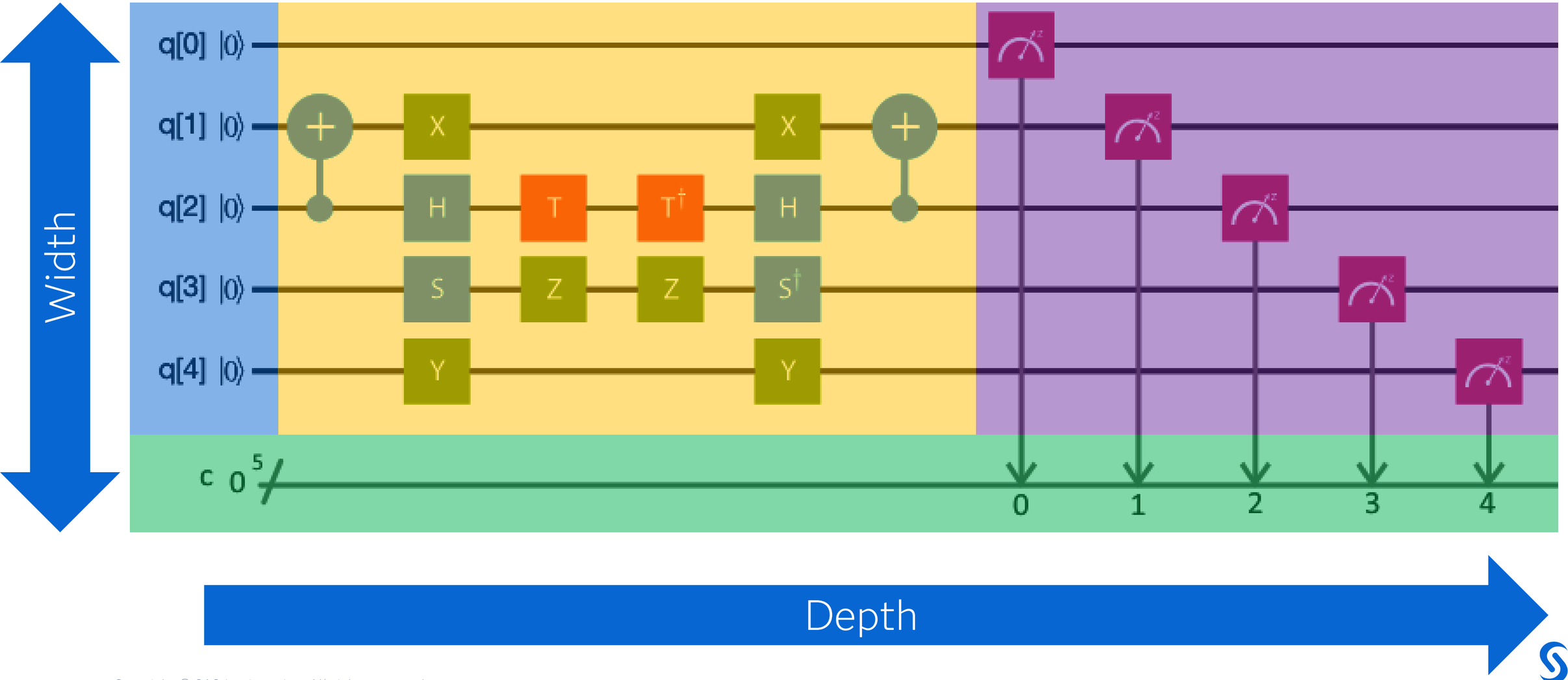
Quantum Circuits (Gates)

- Universal quantum computing
- Use of circuit and gates
- Need fault tolerance and error mitigation

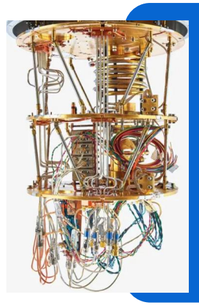
Topological Quantum Computing

- Very early stages
- Resistant to Errors
- Fibonacci Anyons
- Majorana

Noisy Intermediate Scale Quantum (NISQ)
Anatomy of a Quantum Circuit

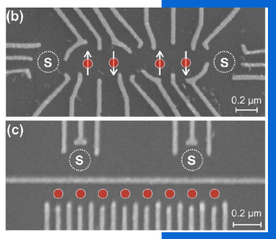


Quantum Computing Modalities



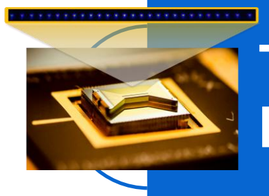
Super-Conducting

- IBM, Google, Rigetti
- Fast Gate Times
- QPU Mapping



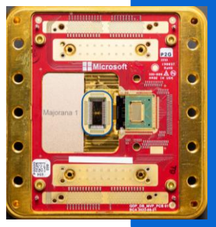
Spin Qubits

- Intel, Diraq
- CMOS Fabrication
- High Connectivity



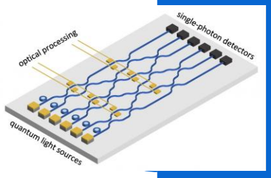
Trapped Ions

- IonQ, Quantinuum
- High Fidelity
- Long Coherence
- All-All Connectivity



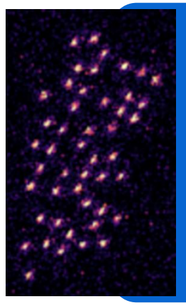
Topological

- Microsoft
- Intrinsic Error Resistant
- Majorana



Photonic

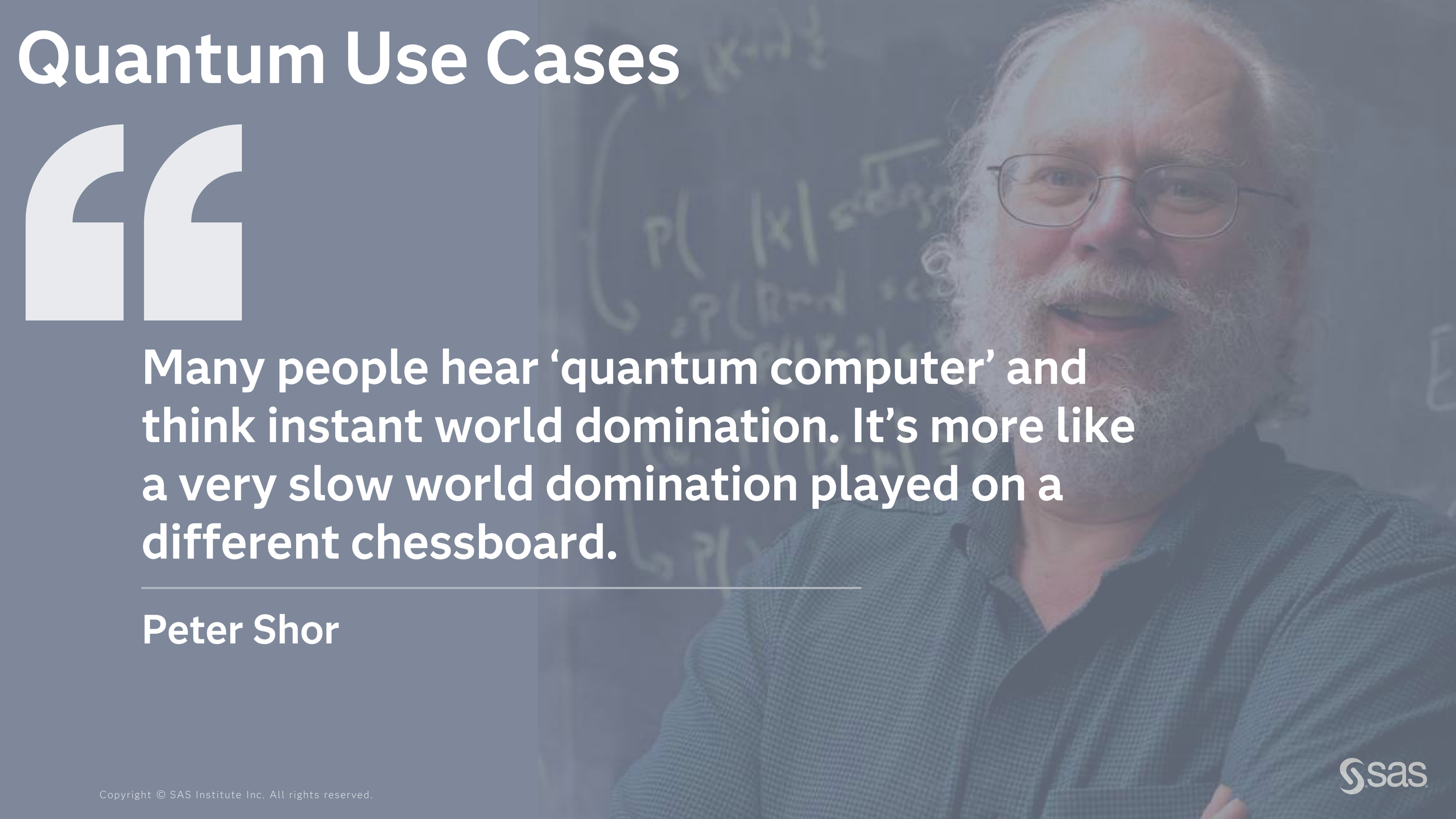
- Xanadu, PsiQuantum
- Room Temperature
- Qudits



Neutral Atoms

- QuEra, Infleqtion, Atom
- Room Temperature
- All-All Connectivity
- Optical Tweezers

Quantum Use Cases



Many people hear ‘quantum computer’ and think instant world domination. It’s more like a very slow world domination played on a different chessboard.

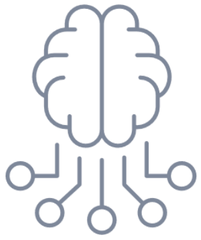
Peter Shor

Optimization

Optimization

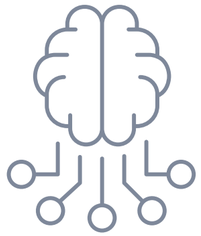
- Complex Combinatorial Relationships
- Exponential Large Solution Spaces
  - Routing
  - Scheduling
  - Supply Chain
  - Resource Allocation
  - Others

Machine Learning



Machine Learning

- Quantum Kernels
- Feature Spaces
- Generative Models
- Predictive Models
- Hybrid QML
- Expressivity & Sampling
- HHL Linear Equations



Simulation

Simulation

- Drug Discovery
- Material Design
- Protein Folding
- Quantum Science
- HHL Linear Equations
- Quantum Monte Carlo

Quantum Computing in Agriculture

Quantum mechanics makes us rethink every assumption in every field – from computing to consciousness.

Seth Lloyd

Optimization Problems

Ration Optimization

- Multi-objective optimization (cost, nutrition, environment).
- Combinatorial explosion at scale.

Feed Supply Chain

- Routing, sourcing, and blending are tightly coupled.
- NP-hard optimization problems.

Resource Allocation

- Competing constraints (land, water, regulation).
- Multi-objective trade-offs limit optimal solutions.

Common challenge: multi-objective, combinatorial optimization at scale.

Learning from Biological Data (QML)

Genomics & Genetic Selection

- Millions of markers → extreme dimensionality.
- Gene interactions → combinatorial explosion.

Precision Livestock & Biosensing

- Continuous, multimodal sensor streams.
- Complex temporal patterns don’t scale.

Animal Health & Epidemiology

- Disease spreads on large contact networks.
- Sparse data + large graph complexity.

Common challenge: high-dimensional learning and combinatorial scaling.

Complex Systems (Simulations)

Feed Additive & Molecular Discovery

- Molecular interactions require quantum-level simulation.
- Classical methods scale poorly with system size.

Systems Biology & Flux Analysis

- Thousands of coupled biochemical reactions.
- Parameter estimation is high-dimensional and non-convex.

Microbiome & Gut Ecosystem

- Thousands of interacting microbial species.
- Predicting system response becomes intractable.

Common challenge: large-scale, coupled simulations with poor classical scaling.

Applied Quantum at SAS

Selected Optimization POC Example

Application by Industry

Insurance

Disaster Response

Risk

Montecarlo

Financial Services

Fraud

Bankruptcy

Collateral Optimization

Portfolio Optimization

Healthcare

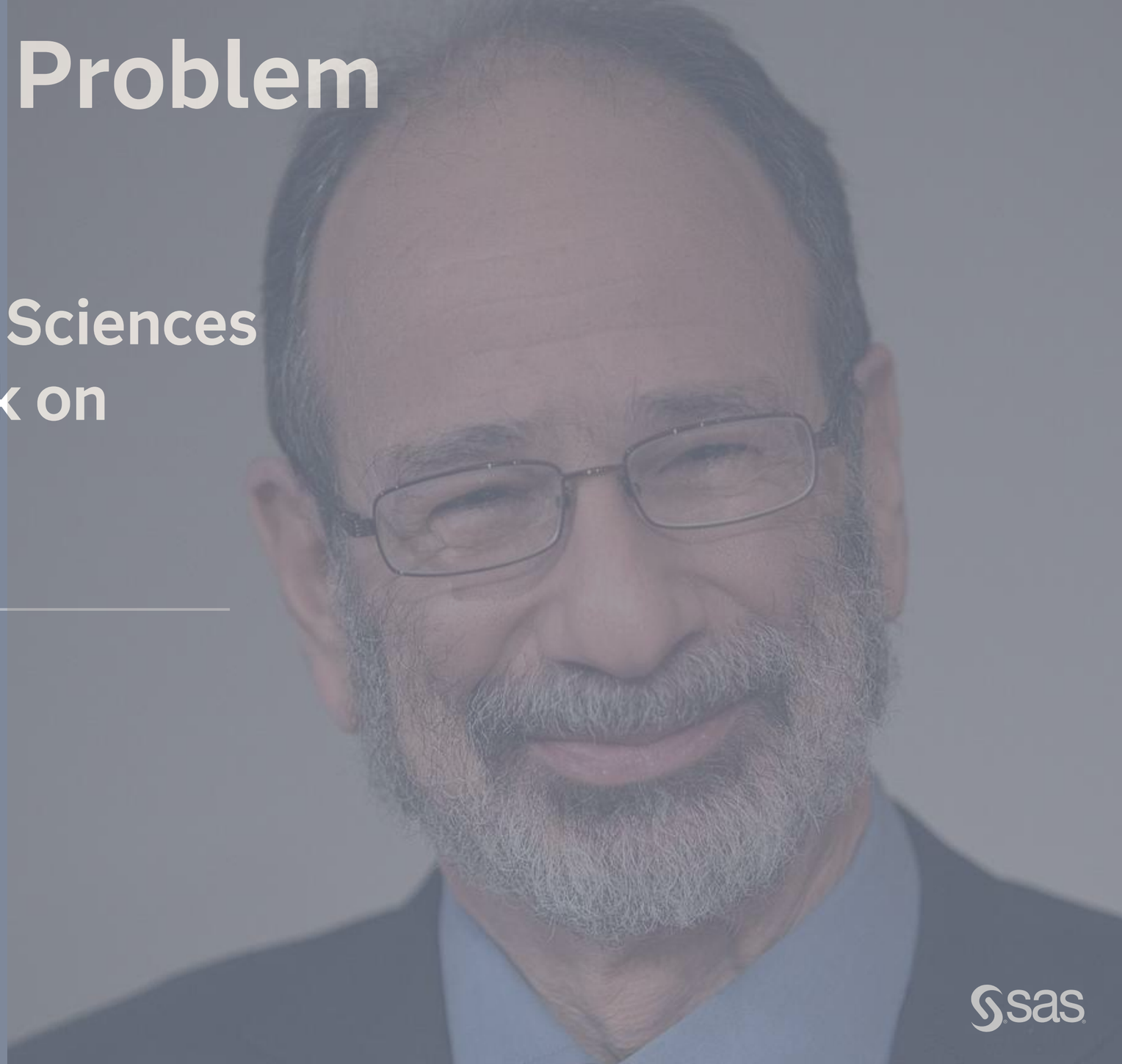
Kidney Exchange

Pharmaceuticals

Image Classification

Digital Twins

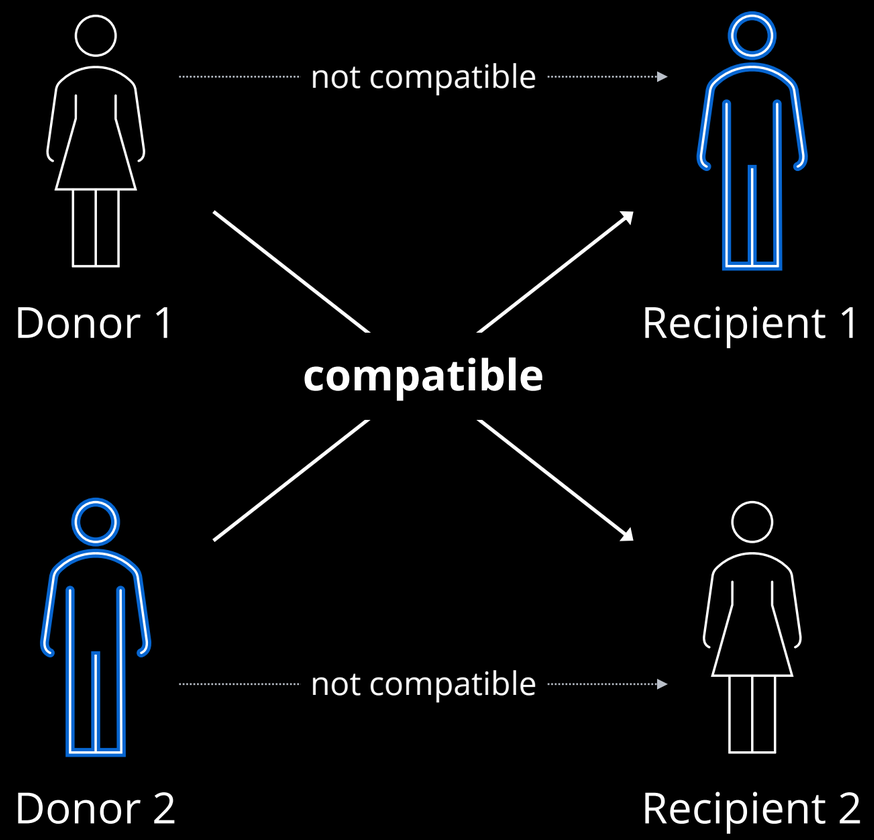
Kidney Exchange Problem



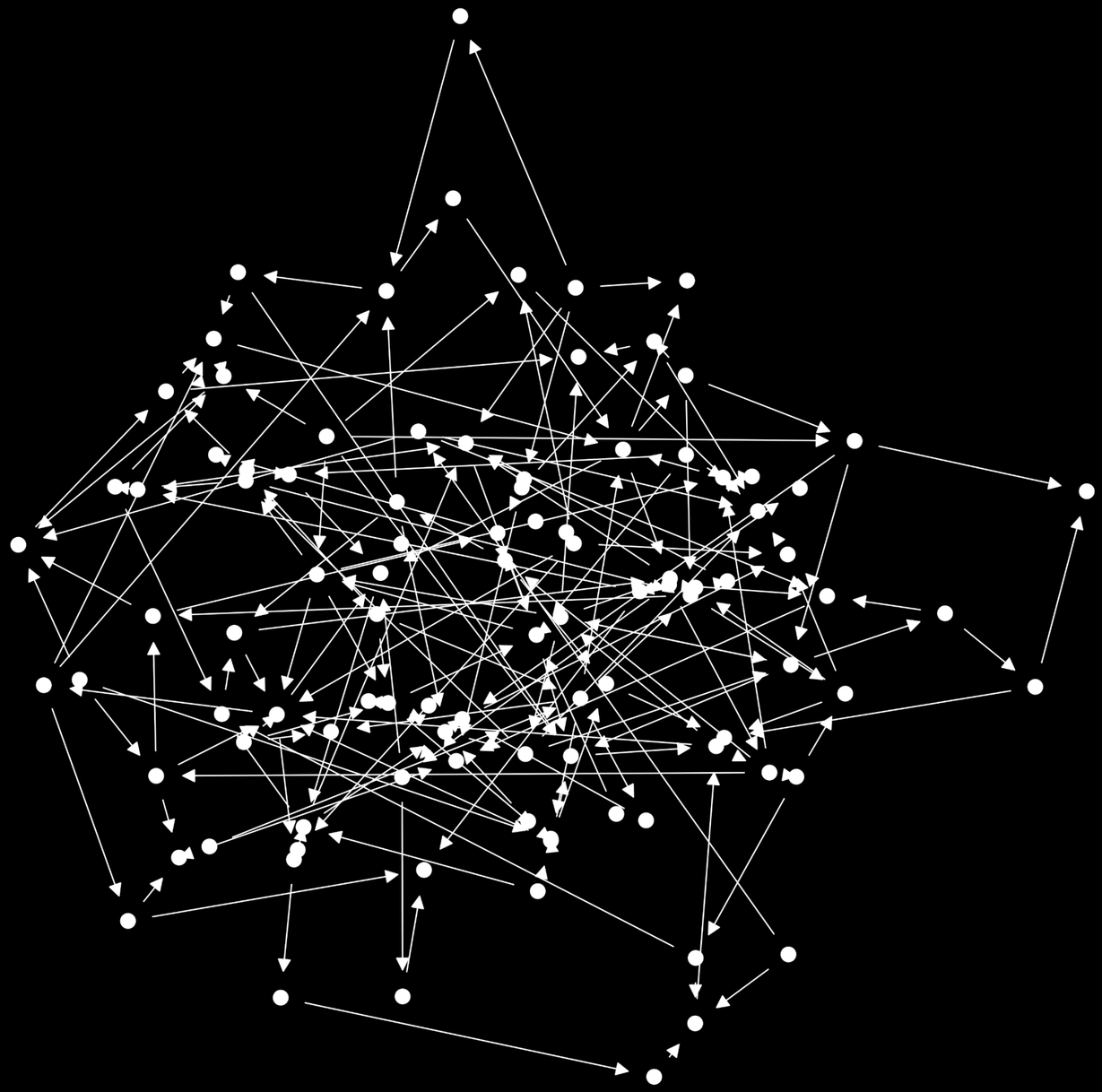
Nobel Prize in Economic Sciences in 2012 for applying work on market design to kidney exchange programs.

Alvin E. Roth

SOLVING KIDNEY EXCHANGE



SOLVING KIDNEY EXCHANGE

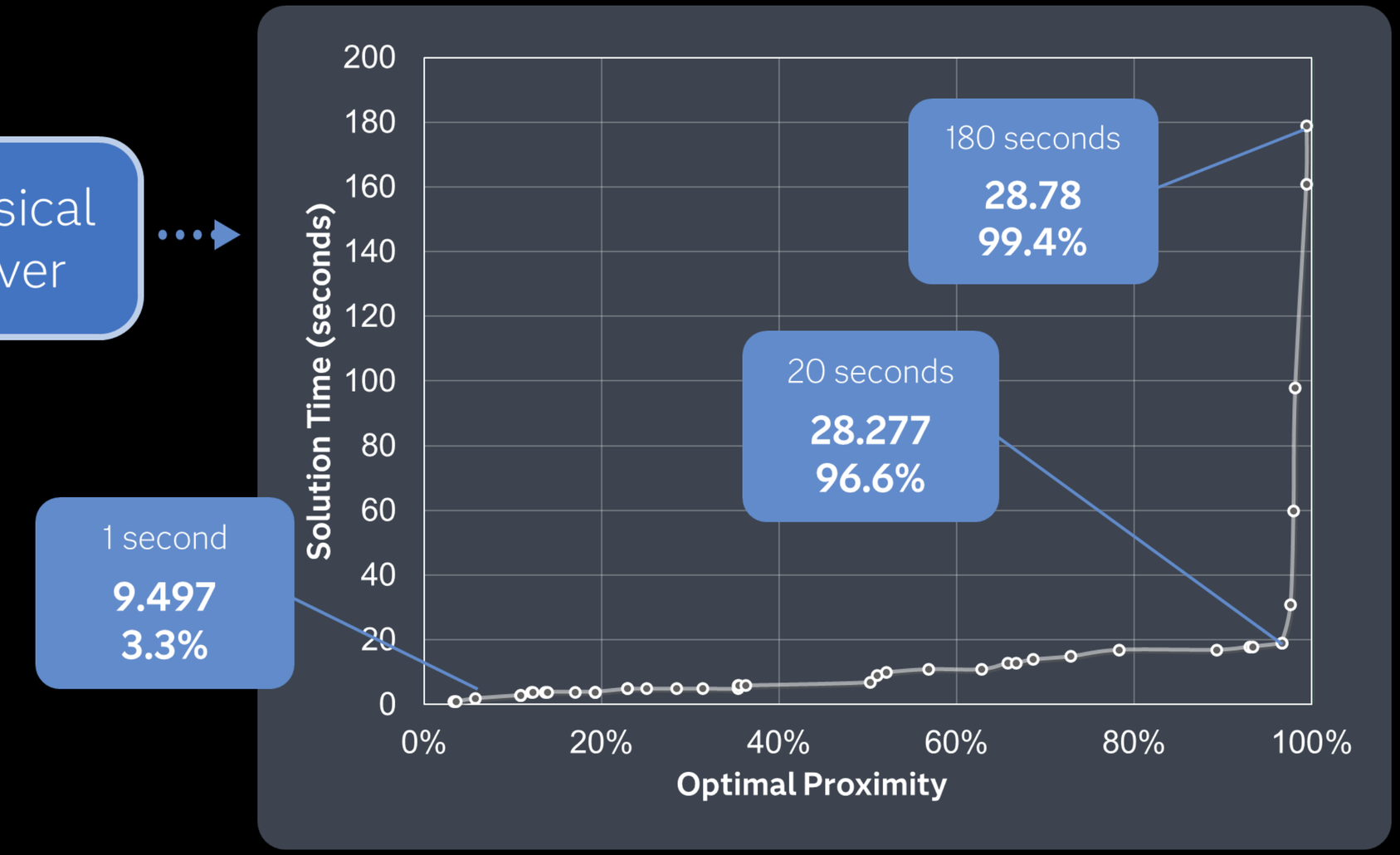


Kidney Exchange Problem – Classical Solve

EXECUTE CLASSICAL SOLVER

$$
\begin{aligned}
\text{maximize} \quad & \sum_{(i,j)\in A} \sum_{m\in M} w_{ij} x_{ijm} \\
\text{subject to} \quad & \sum_{m\in M} y_{im} + s_i = 1 && i \in N && \text{(Packing)} \\
& \sum_{(i,j)\in A} x_{ijm} = y_{im} && i \in N,\ m \in M && \text{(Donate)} \\
& \sum_{(i,j)\in A} x_{ijm} = y_{jm} && j \in N,\ m \in M && \text{(Receive)} \\
& \sum_{(i,j)\in A} x_{ijm} \le L && m \in M && \text{(Cardinality)} \\
& x_{ijm} \in \{0,1\} && (i,j) \in A,\ m \in M \\
& y_{im} \in \{0,1\} && i \in N,\ m \in M \\
& s_i \in \{0,1\} && i \in N
\end{aligned}
$$

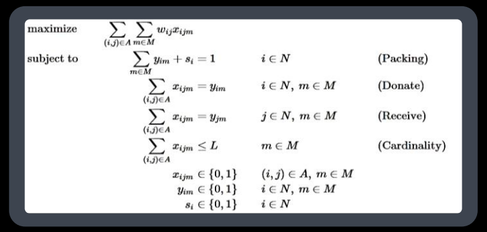
Classical Solver



Getting close to optimal is quick but proving optimality is hard.

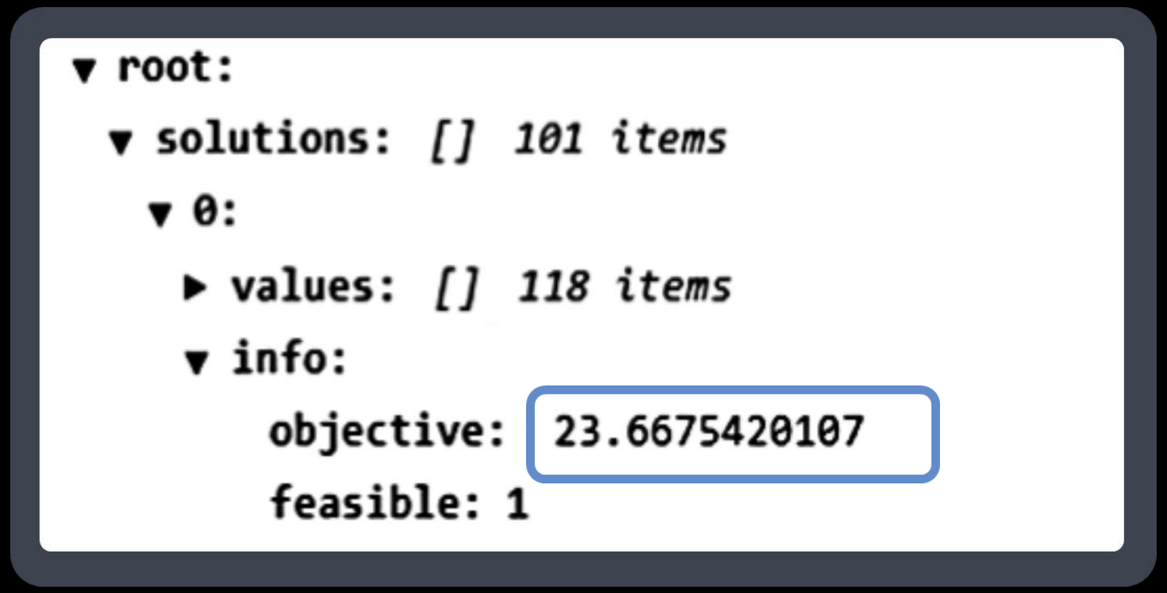
Kidney Exchange Problem – Quantum Solve

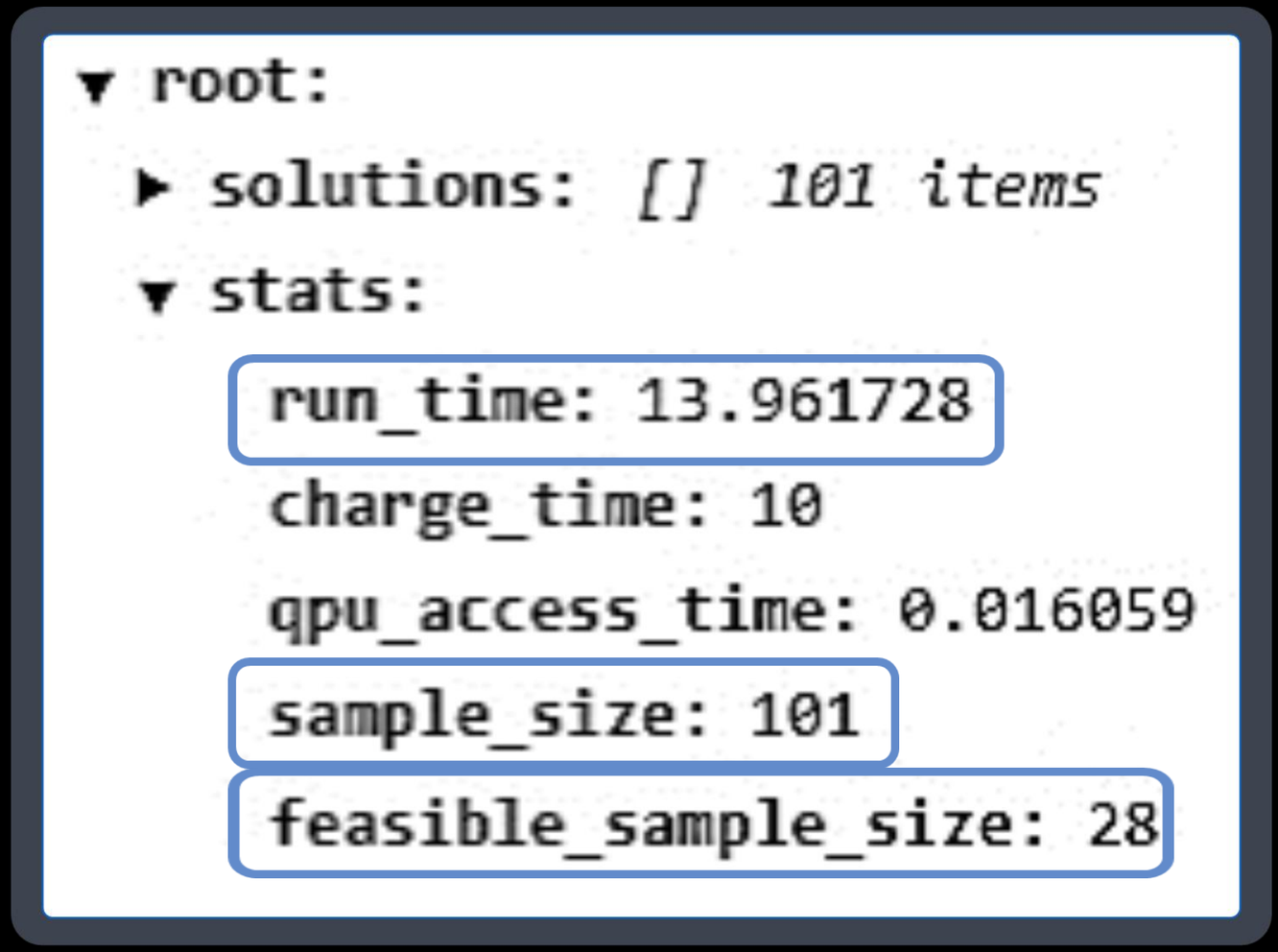
EXECUTE QUANTUM-HYBRID SOLVER



$$
\begin{array}{lll}
\text{maximize} & \sum_{(i,j)\in A}\sum_{m\in M} w_{ij}x_{ijm} & \\
\text{subject to} & \sum_{m\in M} y_{im} + s_i = 1 & i \in N \quad \text{(Packing)} \\
& \sum_{(i,j)\in A} x_{ijm} = y_{im} & i \in N,\ m \in M \quad \text{(Donate)} \\
& \sum_{(i,j)\in A} x_{ijm} = y_{jm} & j \in N,\ m \in M \quad \text{(Receive)} \\
& \sum_{(i,j)\in A} x_{ijm} \le L & m \in M \quad \text{(Cardinality)} \\
& x_{ijm} \in \{0,1\} & (i,j) \in A,\ m \in M \\
& y_{im} \in \{0,1\} & i \in N,\ m \in M \\
& s_i \in \{0,1\} & i \in N
\end{array}
$$

Hybrid Quantum Solver





Quantum gives high-quality solutions fast.

Kidney Exchange Problem – Hybrid Solve

TWO STAGE APPROACH

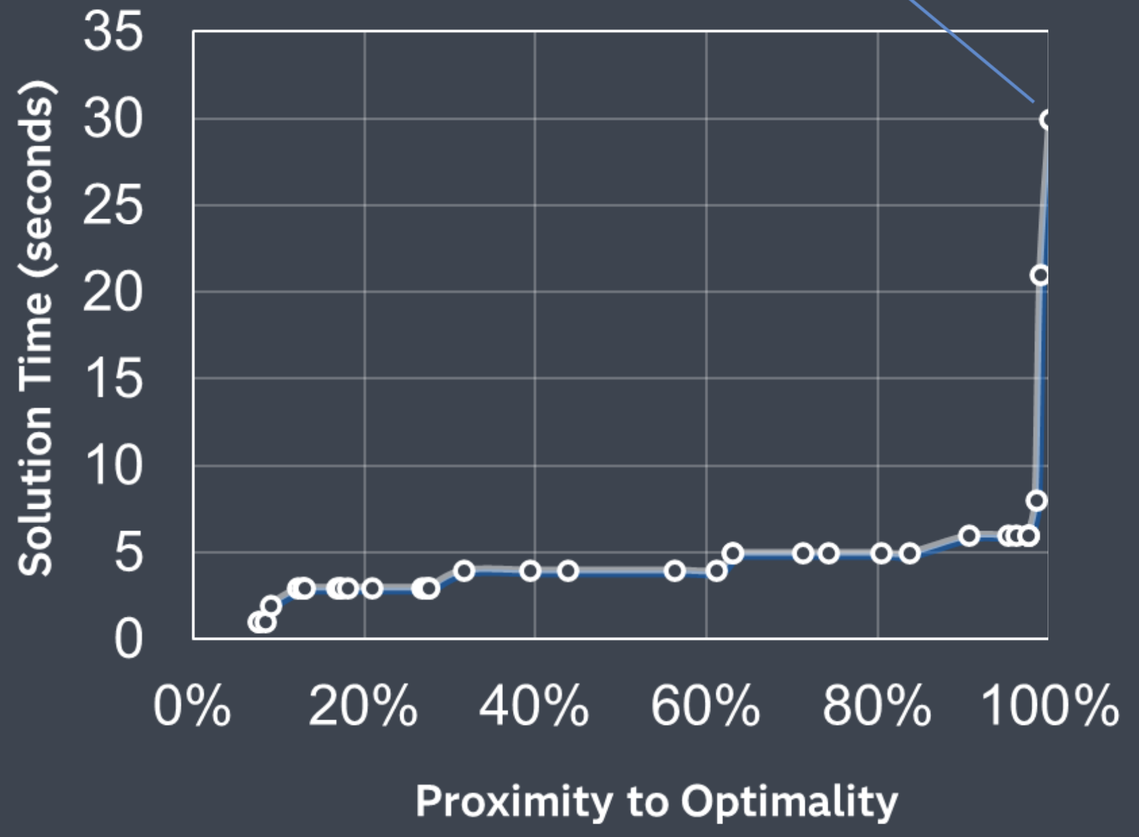
$$
\begin{aligned}
\text{maximize} \quad & \sum_{(i,j)\in A}\sum_{m\in M} w_{ij} x_{ijm} & & \\
\text{subject to} \quad & \sum_{m\in M} y_{im} + s_i = 1 & i \in N & \text{(Packing)} \\
& \sum_{(i,j)\in A} x_{ijm} = y_{im} & i \in N,\ m \in M & \text{(Donate)} \\
& \sum_{(i,j)\in A} x_{ijm} = y_{jm} & j \in N,\ m \in M & \text{(Receive)} \\
& \sum_{(i,j)\in A} x_{ijm} \le L & m \in M & \text{(Cardinality)} \\
& x_{ijm} \in \{0,1\} & (i,j) \in A,\ m \in M & \\
& y_{im} \in \{0,1\} & i \in N,\ m \in M & \\
& s_i \in \{0,1\} & i \in N &
\end{aligned}
$$

Classical Solver

Hybrid Quantum Solver

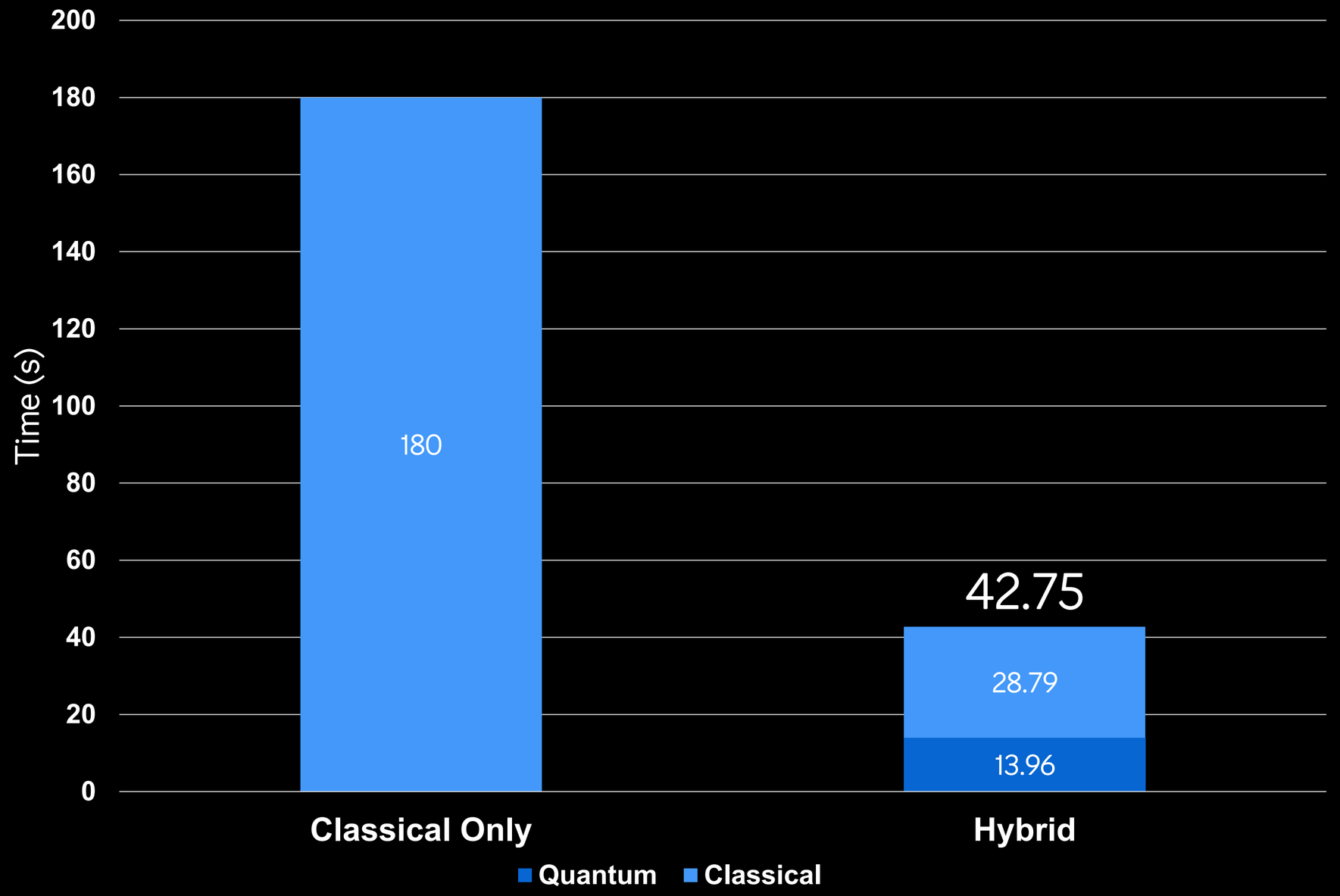
```
▼ root:
  ▶ solutions: [] 101 items
  ▼ stats:
      run_time: 13.961728
      charge_time: 10
      qpu_access_time: 0.016059
      sample_size: 101
      feasible_sample_size: 28
```

30 seconds
28.793
100%



Hybrid combines speed and proof.

Kidney Exchange Problem Comparison



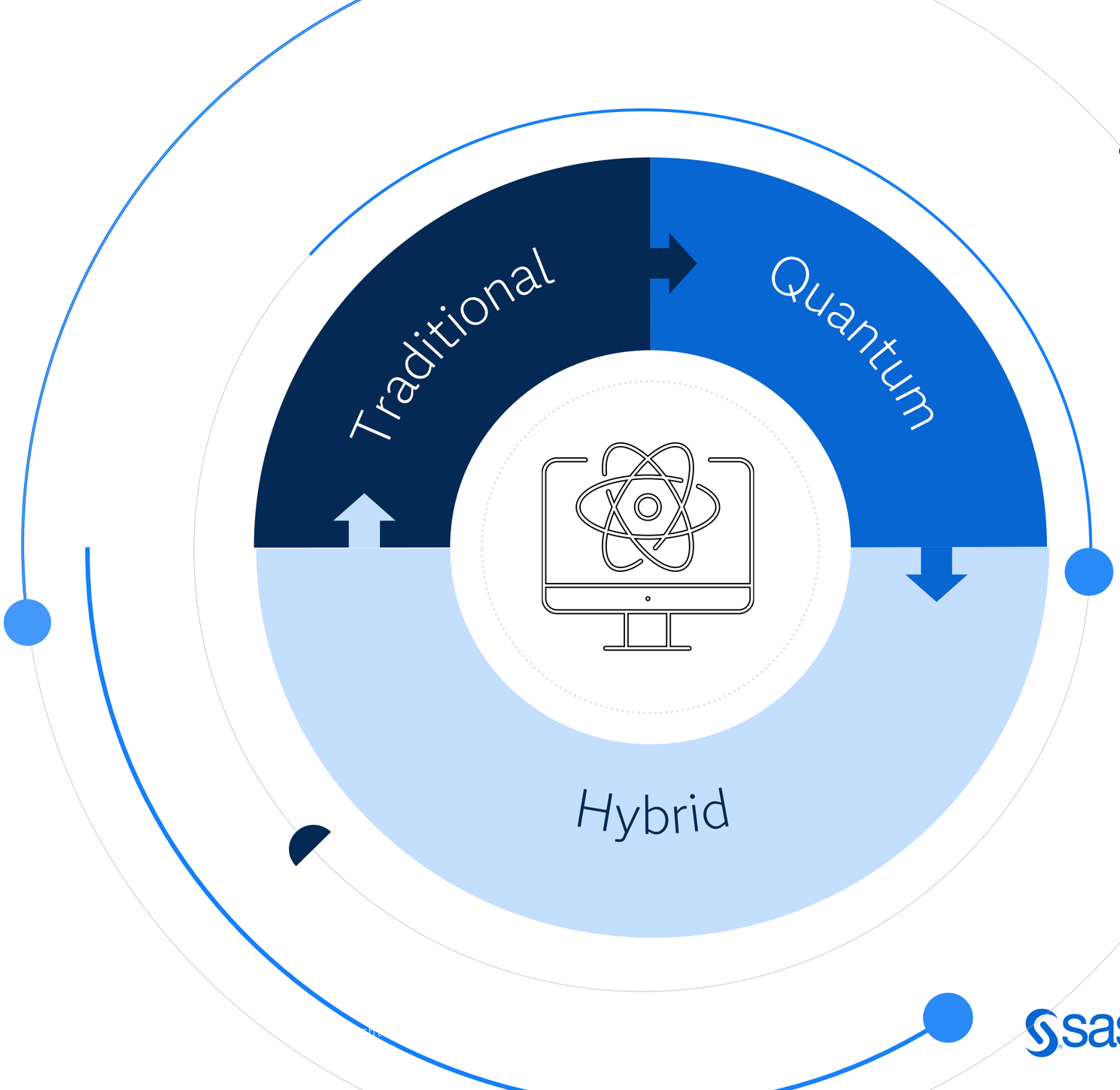
Quantum @ SAS

All Roads Lead to Hybrid

Pre-processing
Exploration
Baselines
Post-process

Projections
Data Generation
Feature Selection
Kernels

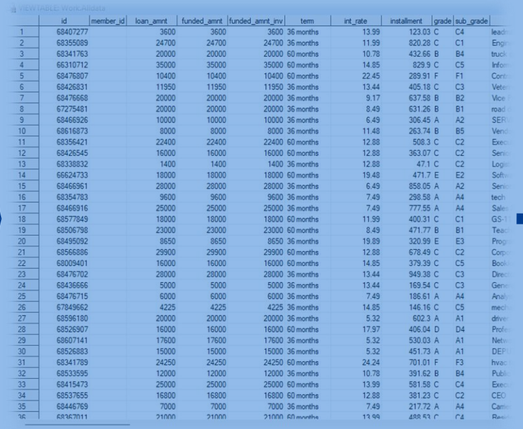
Hybrid



DATA ACCESS

DATA INTEGRATION

DATA OPTIMIZATION



DATA MINING

DATA SCIENCE

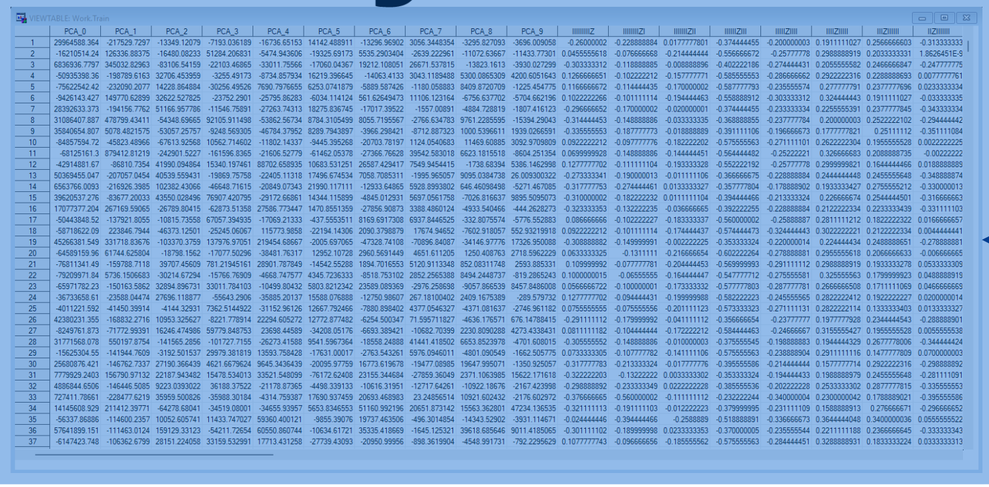
DATA TRANSFORMATION

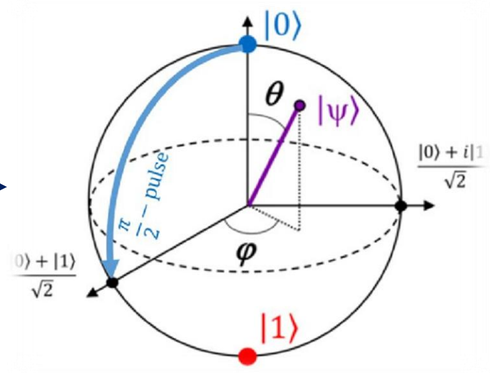
REPORTING

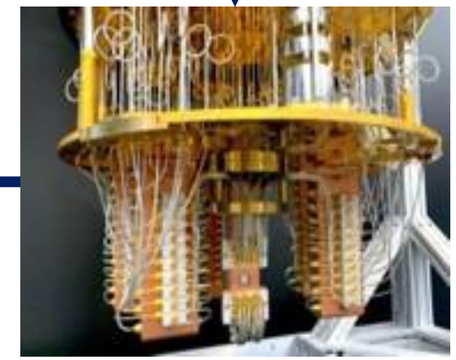
DATA FILTER

DATA VALIDATION

sas viya

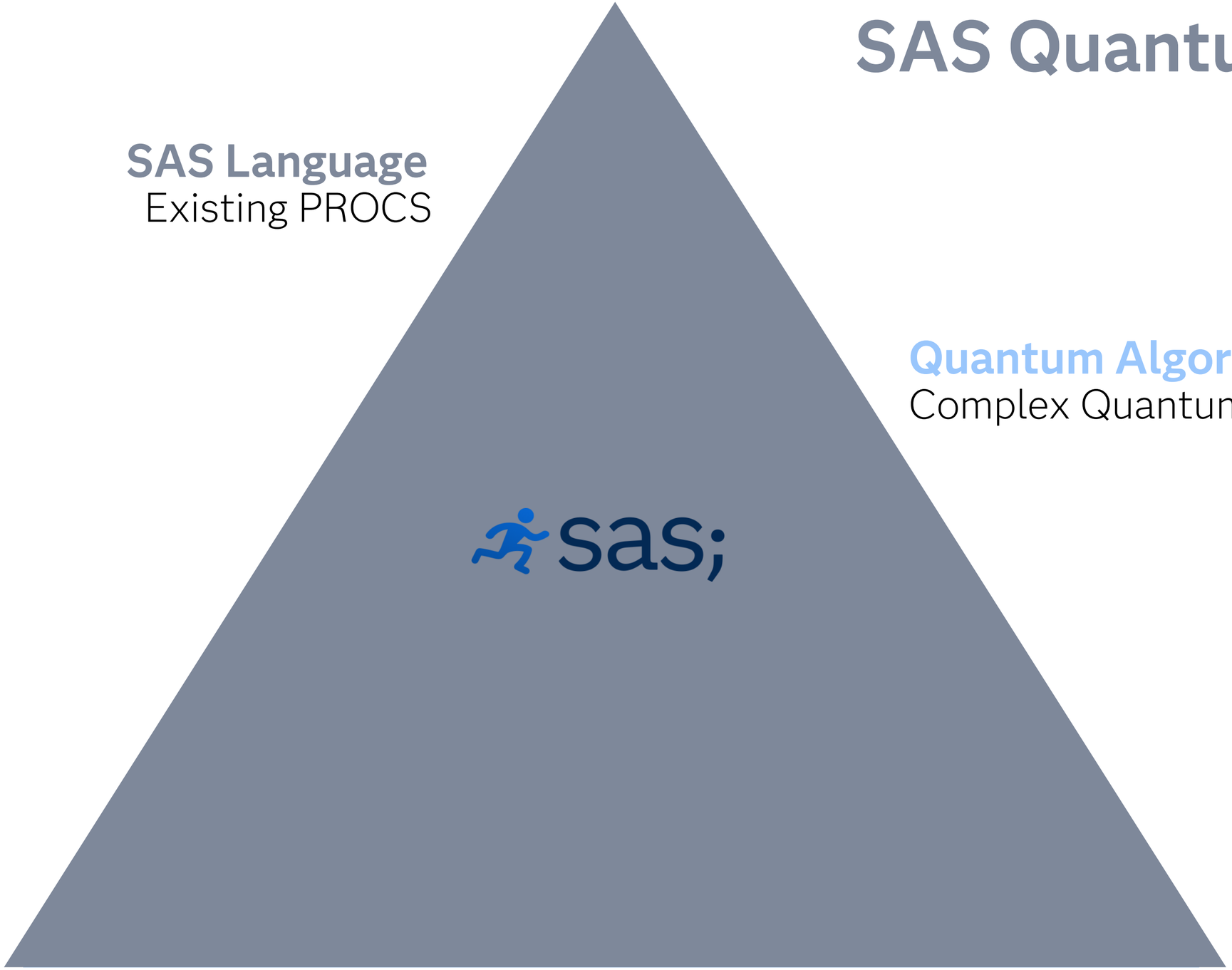






SAS Quantum Lab

SAS Language
Existing PROCS



Quantum Algorithms
Complex Quantum Circuits

Let’s Chat?

Bill.Wisotsky@sas.com

Principal Quantum Systems Architect