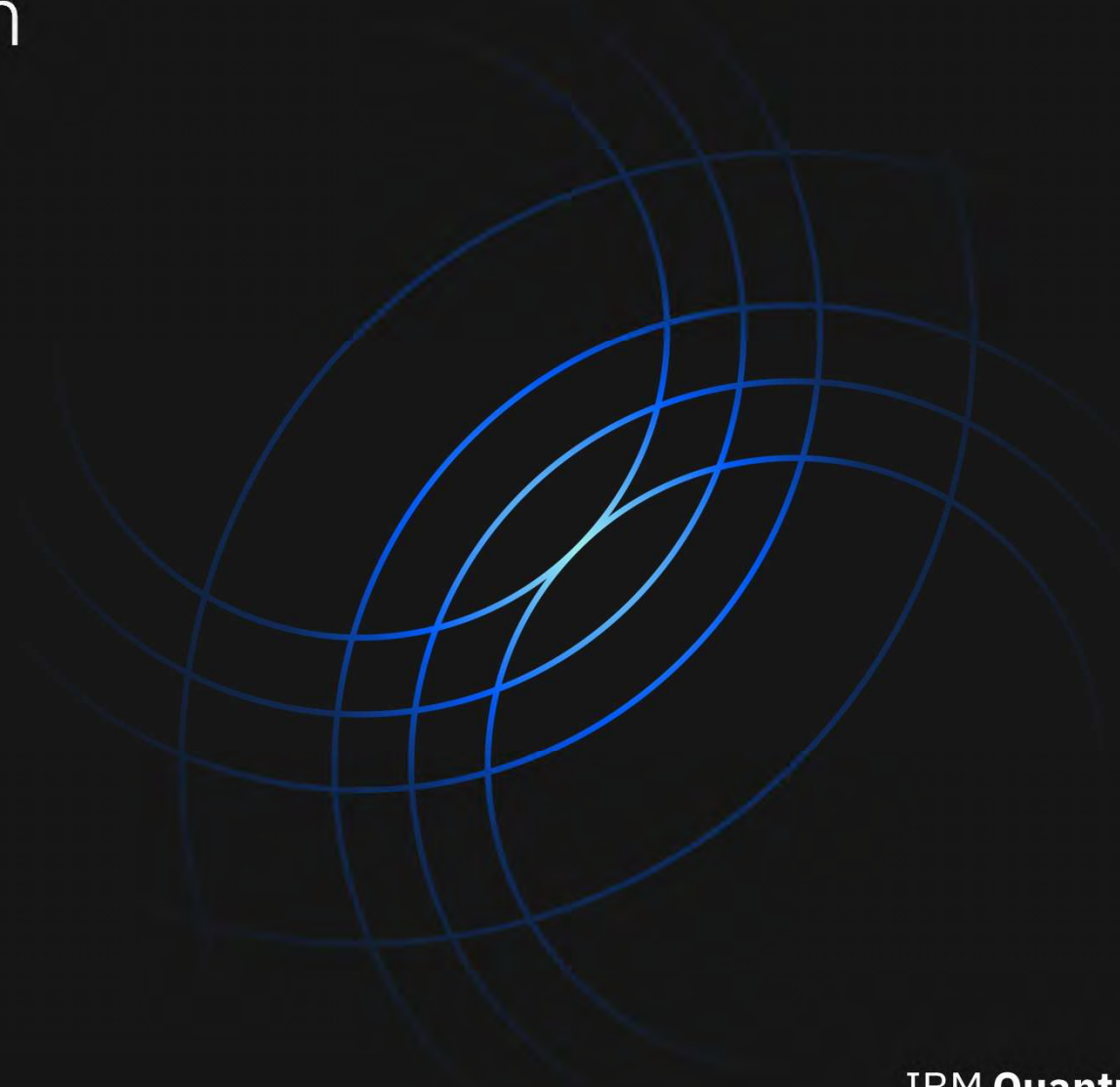


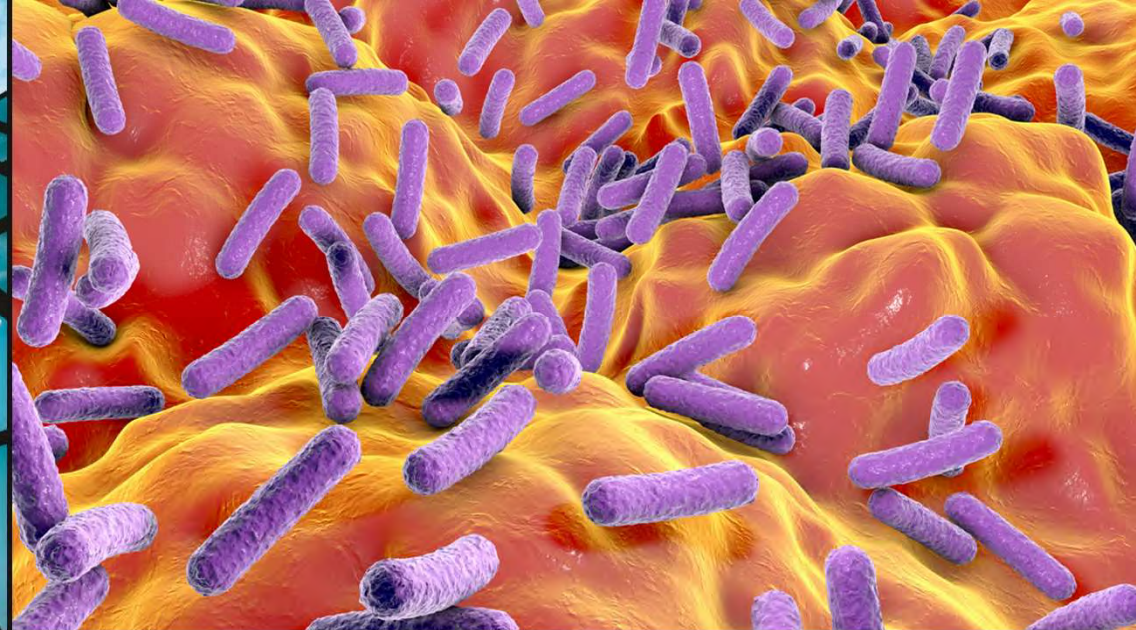
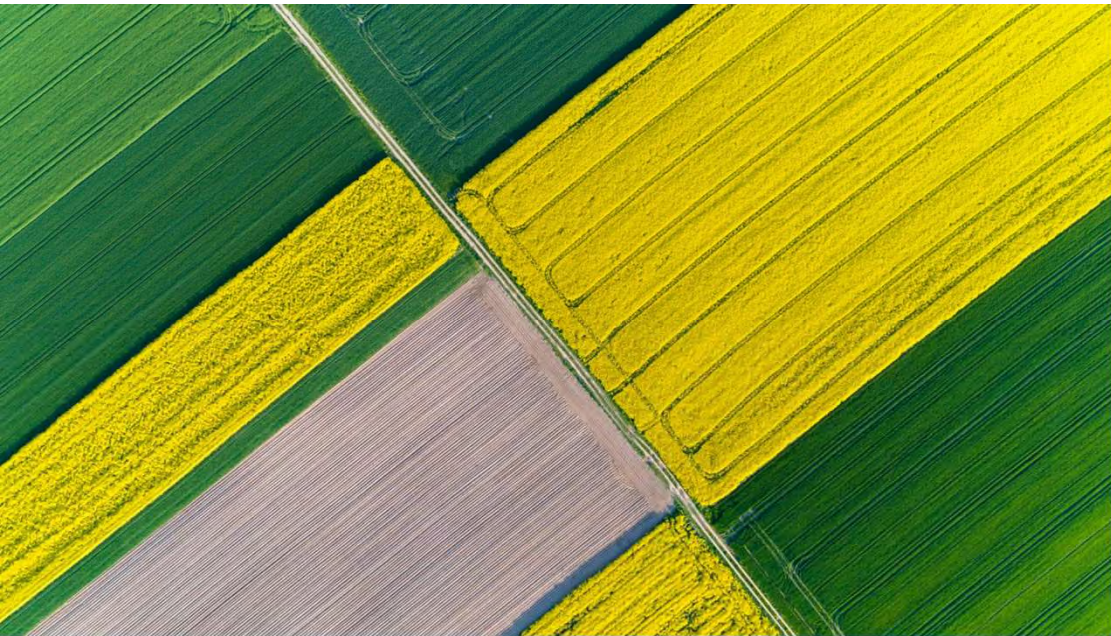
# Introduction to Quantum Computing

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Teppo Seesto  
IBM Quantum Ambassador



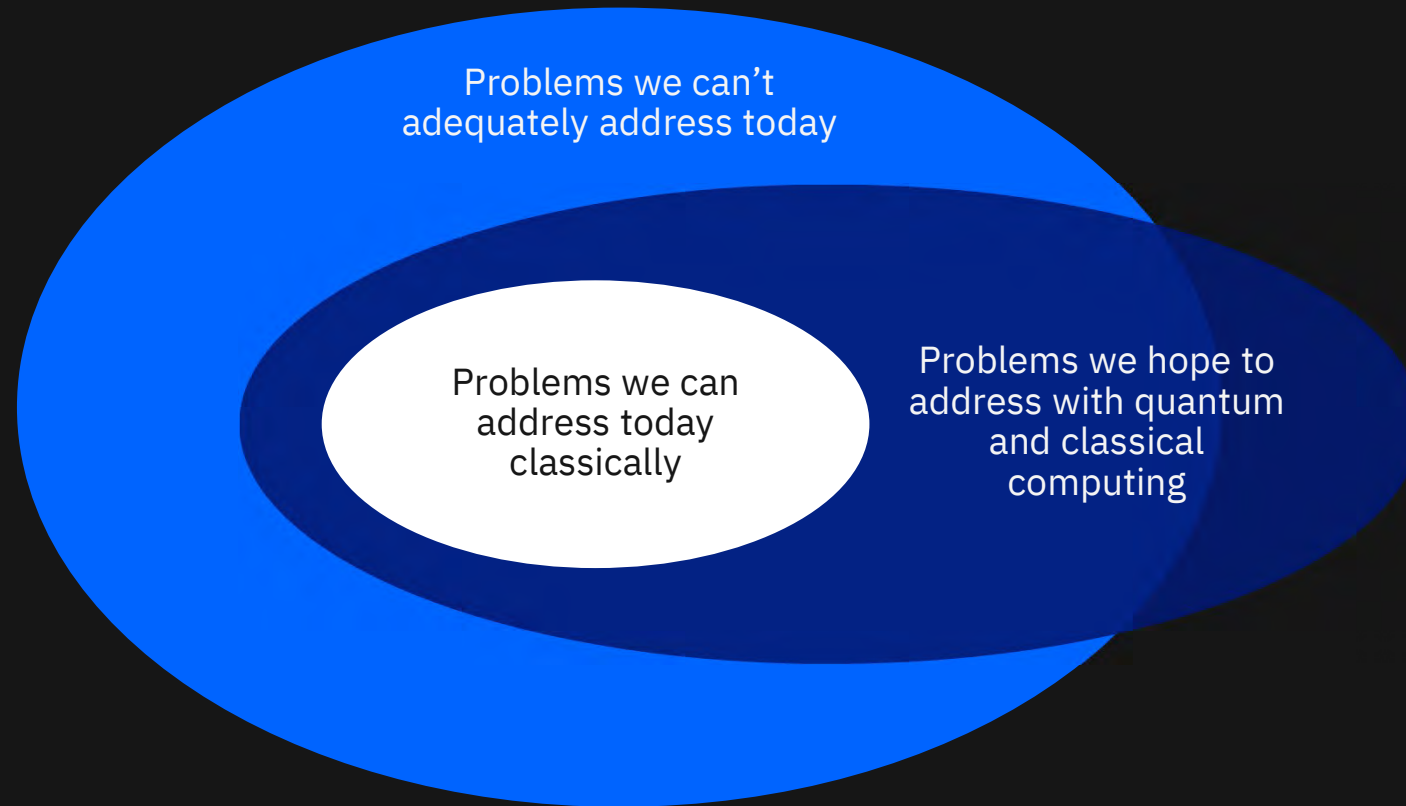






# Why quantum?

IBM Quantum



Despite how sophisticated digital “classical ” computing has become, there are many scientific and business problems for which we’ve barely scratched the surface.

# Quantum applications span three general areas

Simulating Quantum Systems

Artificial Intelligence

Optimization



Quantum chemistry  
Material science  
High energy physics



Better model training  
Pattern recognition  
Fraud detection



Route optimization  
Manufacturing Supply Chain  
Portfolio optimization  
Risk analysis  
Loans & credit scoring  
Monte Carlo-like applications

# Mercedes-Benz Group

New materials

Manufacturing analysis

Product recommendation

## Quantum Computing for Materials Discovery and Manufacturing Optimization

Daimler and IBM have recently published a series of papers demonstrating progress toward using quantum computers to model material systems including Lithium-sulfur that are relevant to advancing the performance of batteries. The teams have also demonstrated applications in manufacturing defect analysis and product recommendation.



“Developing and perfecting these hypothetical batteries could unlock a billion-dollar opportunity.”

### **Benjamin Boeser**

[Former] Director of Innovation Management,  
Silicon Valley at Mercedes-Benz R&D North America

# JP Morgan Chase

## Option pricing

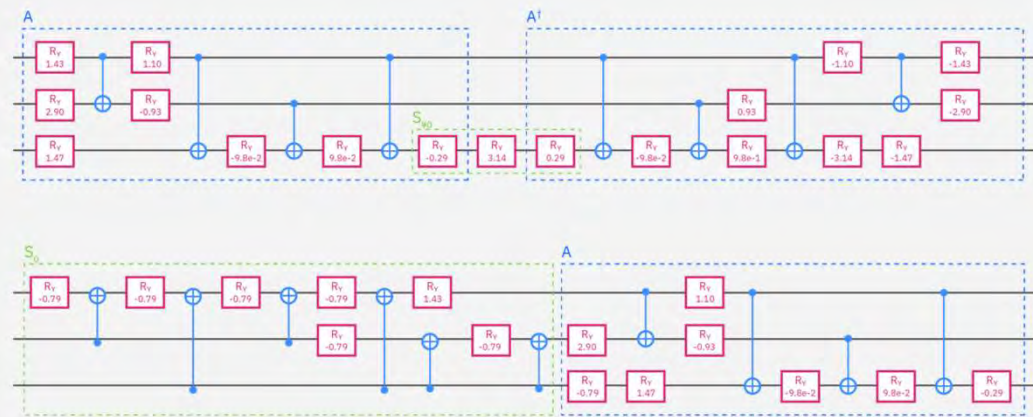
### Quantum Computing for the Financial Services Industry

Recently, JPMC and IBM used Quantum Amplitude Estimation, a Monte Carlo-like sampling algorithm, to compute European option pricing, pricing path depend options, showing a quadratic speed-up versus a classical Monte Carlo approach.



IBM Quantum

European derivative pricing circuit





# ExxonMobil

## Route optimization

### Maritime Routing's Mind-Boggling Math

In 2021 more than 500 LNG (liquified natural gas) ships are used to transport critical fuel supplies across the oceans. Together, they make thousands of journeys per year to destination ports where the LNG is deployed to power critical infrastructure.

Finding optimal routes for a fleet of such ships can be a mind-bendingly complex optimization problem.

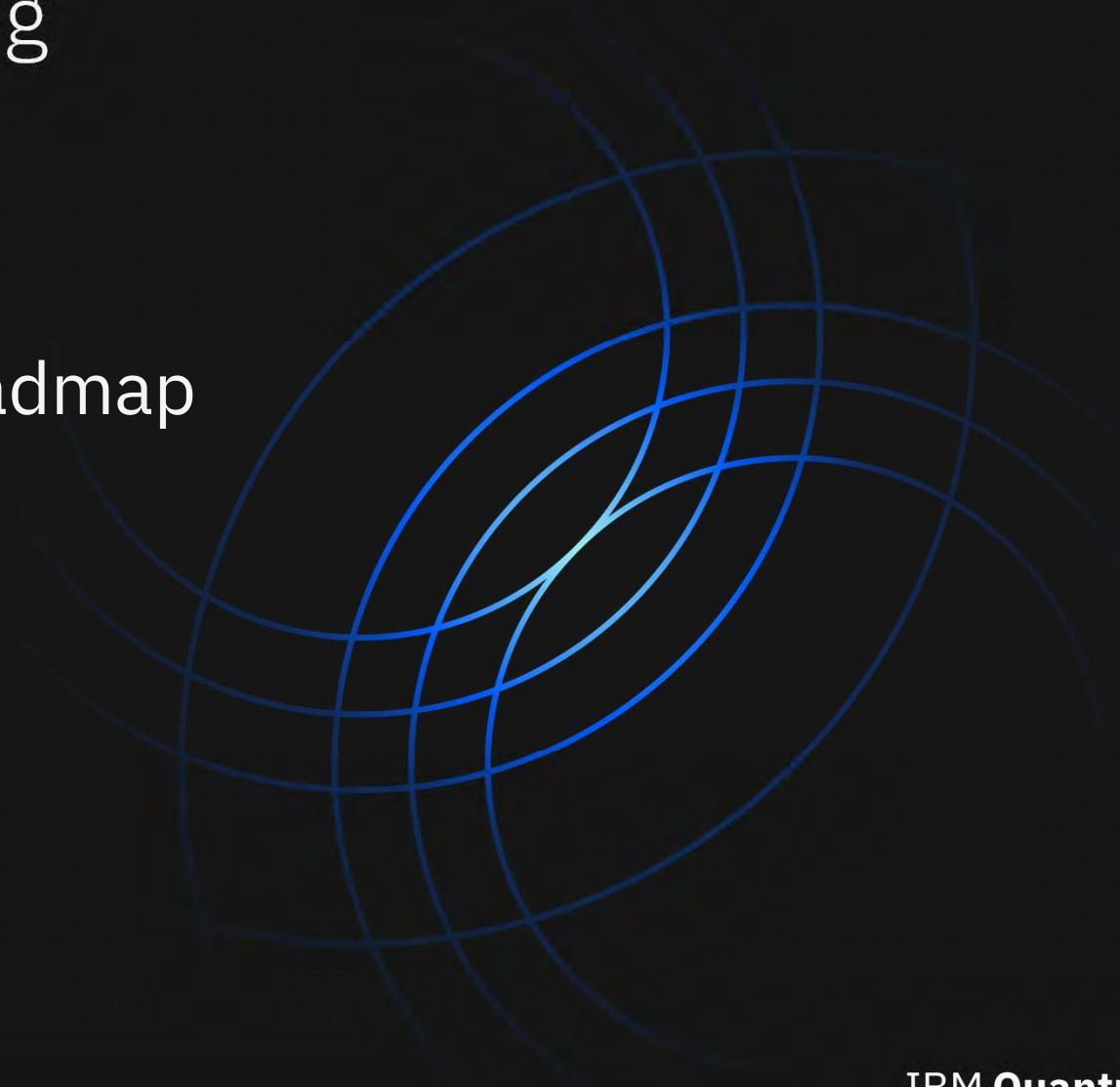


Quantum computers take a new approach to addressing this sort of complexity, with the potential to find solutions that classical supercomputer alone cannot handle. Industry leaders like Exxon are getting involved now to explore how blending classical and quantum computing techniques might solve big, complex, pressing global challenges.

# IBM Quantum Computing

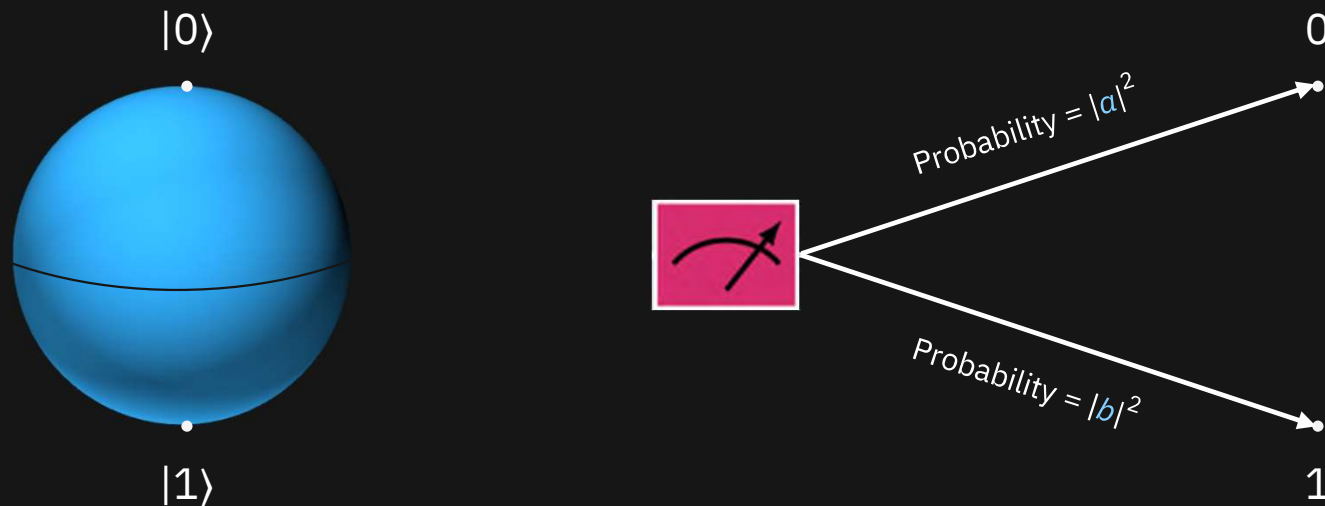
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## Quantum computer and roadmap





# Bits and qubits



A qubit's **state** is a combination of  $|0\rangle$  and  $|1\rangle$ :

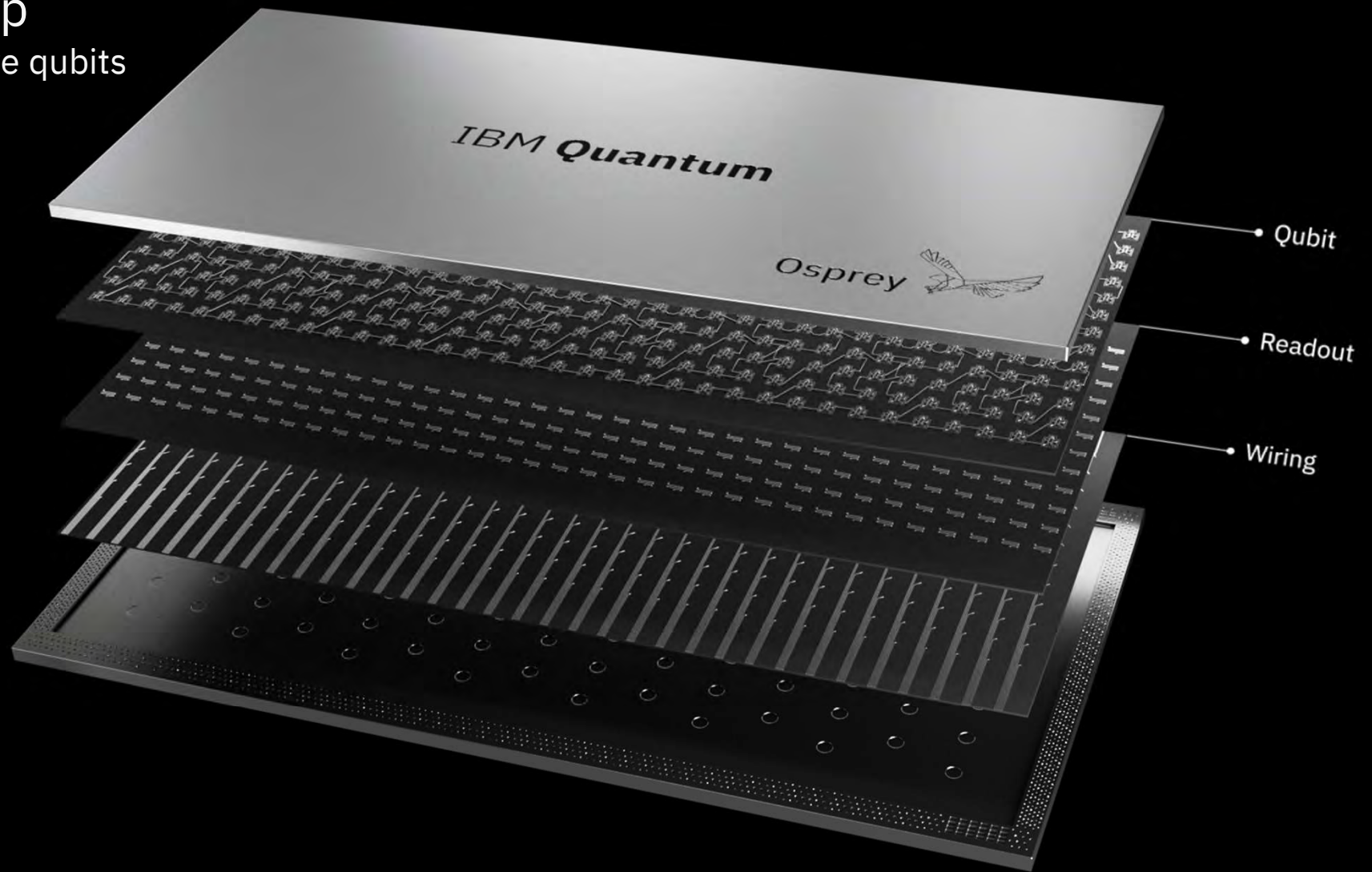
$$a |0\rangle + b |1\rangle$$

This means that a single qubit contains **two** pieces of information.

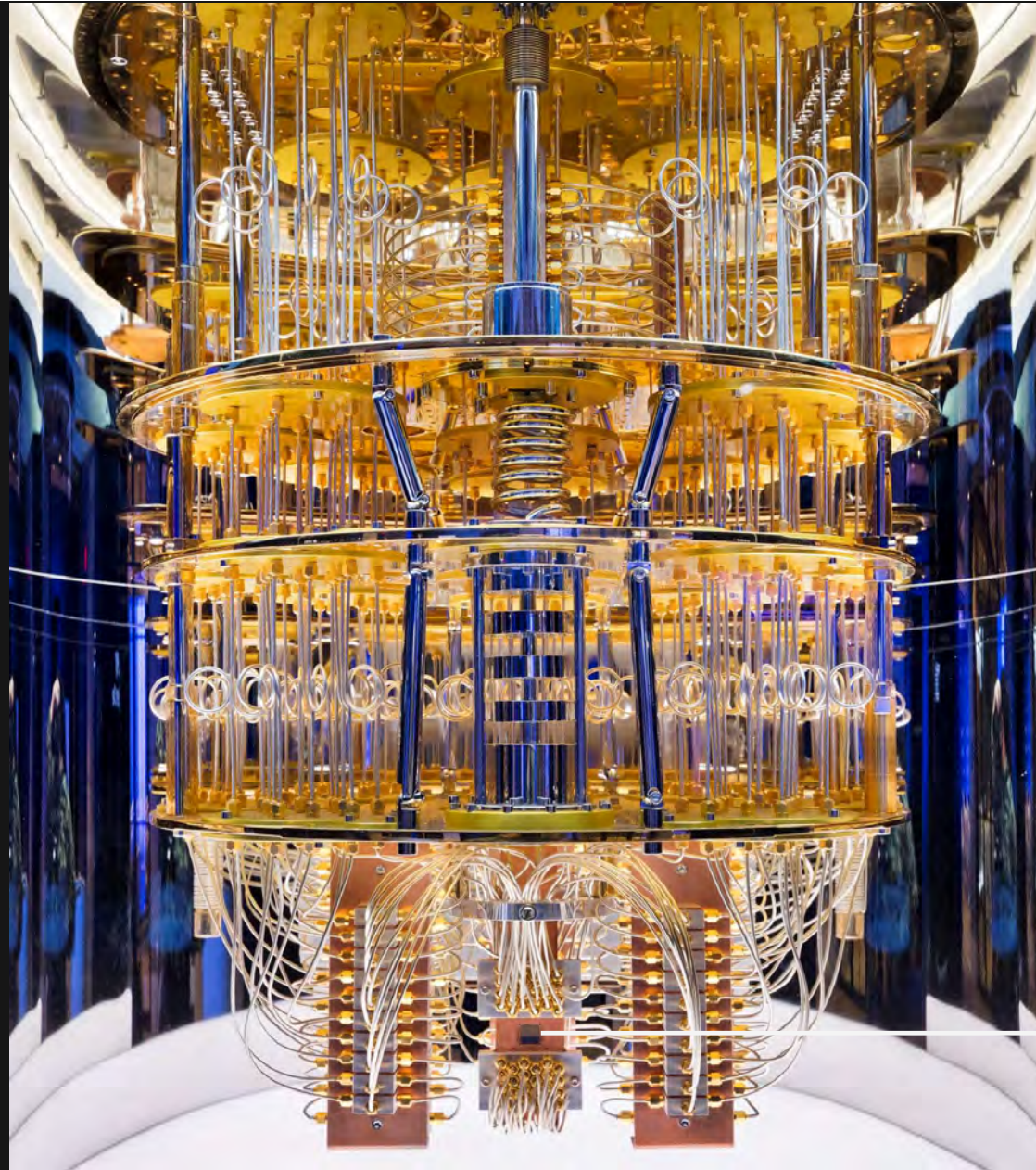
When we measure a qubit, it becomes **0** or **1** based on probability.

# Osprey Chip

Superconductive qubits



Chandelier



Quantum chip



# IBM Q System One





IBM Q  
System One

IBM

Chandelier


# Development Roadmap

Executed by IBM   
On target 


IBM Quantum

2019 


Run quantum circuits on the IBM cloud

2020 

Demonstrate and prototype quantum algorithms and applications

2021 

Run quantum programs 100x faster with Qiskit Runtime

2022 

Bring dynamic circuits to Qiskit Runtime to unlock more computations

2023

Enhancing applications with elastic computing and parallelization of Qiskit Runtime

2024

Improve accuracy of Qiskit Runtime with scalable error mitigation


2025

Scale quantum applications with circuit knitting toolbox controlling Qiskit Runtime

2026+

Increase accuracy and speed of quantum workflows with integration of error correction into Qiskit Runtime


Model Developers

Prototype quantum software applications 

Quantum software applications

Machine learning | Natural science | Optimization

Algorithm Developers

Quantum algorithm and application modules 

Machine learning | Natural science | Optimization

Quantum Serverless 

Intelligent orchestration

Circuit Knitting Toolbox

Circuit libraries

Kernel Developers

Circuits 

Qiskit Runtime 

Dynamic circuits 

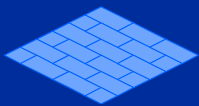
Threaded primitives 

Error suppression and mitigation

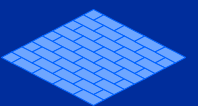
Error correction


System Modularity

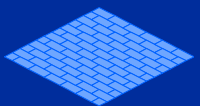
Falcon 27 qubits 



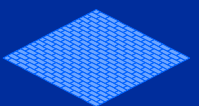
Hummingbird 65 qubits 




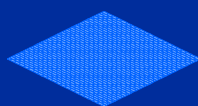
Eagle 127 qubits 



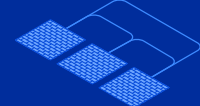
Osprey 433 qubits 



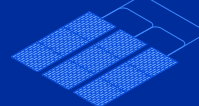
Condor 1,121 qubits 




Flamingo 1,386+ qubits

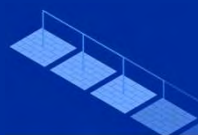


Kookaburra 4,158+ qubits

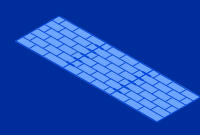


Scaling to 10K-100K qubits with classical and quantum communication

Heron 133 qubits x p 



Crossbill 408 qubits



# Helsingin Sanomat Optio

19.8.2023

**BLUEFORS**





# IBM Quantum – On the cloud since May 2016

Over 460,000 registered users have run ...  
more than 25 quantum computing systems  
on the IBM Cloud, and written over  
2100+ scientific and research papers  
Open source development environment

**Free access:** <https://quantum-computing.ibm.com>

IBM Quantum



# 4 distinct and **simple** IBM Quantum offerings to enable clients on their Quantum journey

## Open Plan

Free Qiskit Runtime service on a limited set of small quantum systems and simulators. Available to all.

## Pay-As-You-Go Plan

*Qiskit Runtime service on IBM Cloud with access to 27 and 127 Qbit IBM quantum systems accessible with Pay-As-You-Go pricing (or Cloud subscription). IBM Cloud account required.*

## Premium Plan

Qiskit Runtime service on IBM's most advanced quantum systems, purchased by reserved capacity. Available directly through IBM Quantum or IBM Quantum Partners ("Hubs") who sub-license their Premium plan access.

## Quantum Accelerator

Engage with our quantum and industry experts to develop your technical and business readiness for quantum computing.

# IBM Quantum Computation Centers (QCC)

IBM Quantum

Centers with dedicated Quantum Systems committed to advancing industry-specific initiatives or regional quantum ecosystems

IBM Quantum  
datacenter in NY

Fraunhofer  
Dec 2020

University of Tokyo  
Jun 2021

Cleveland Clinic  
Mar 2023

PINQ<sup>2</sup>  
Projected 2023

Yonsei  
Projected 2023

BasQ  
Projected 2025





