KPMG

Quantum Computers – available platforms and current capabilities
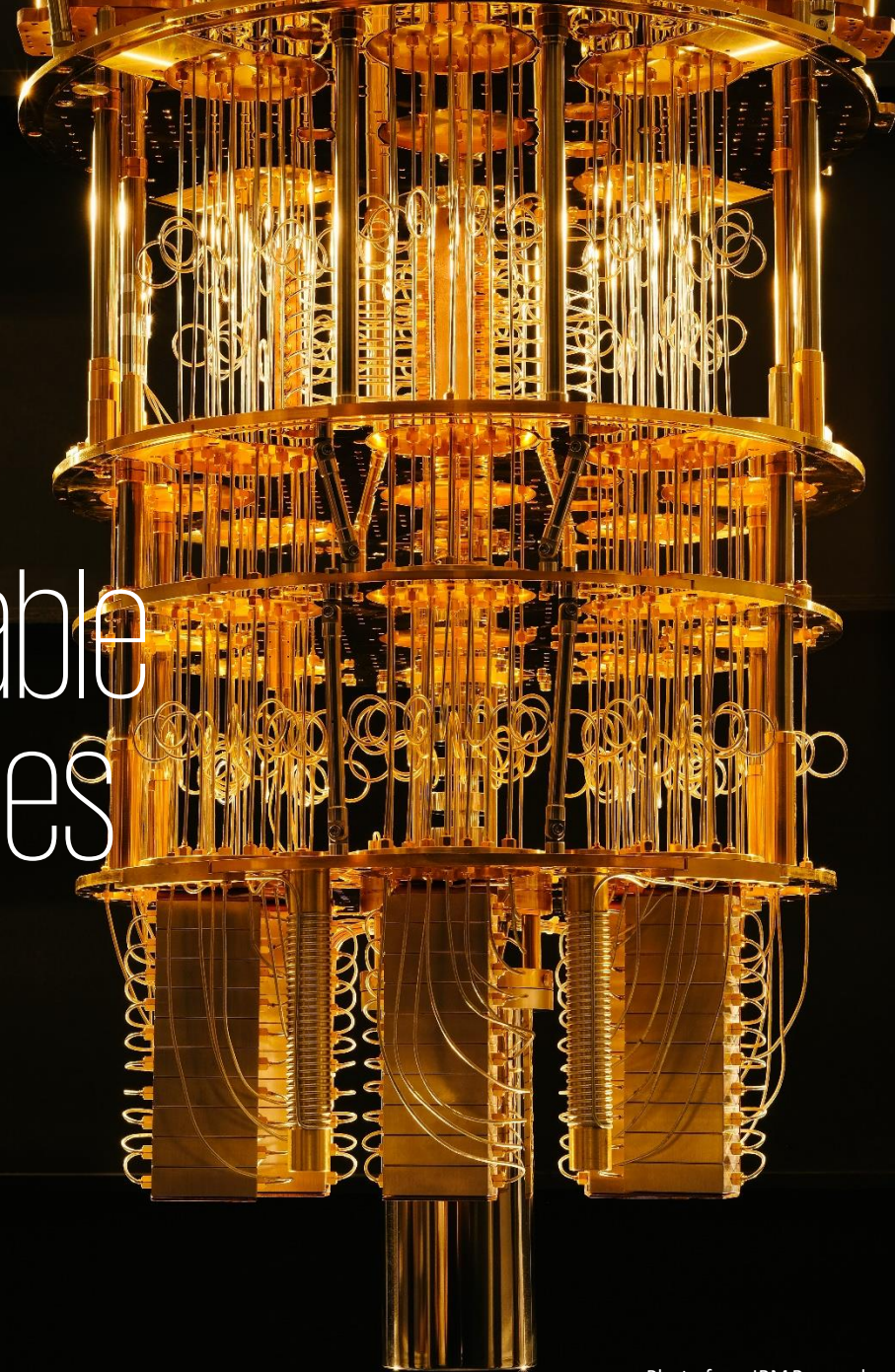
2022

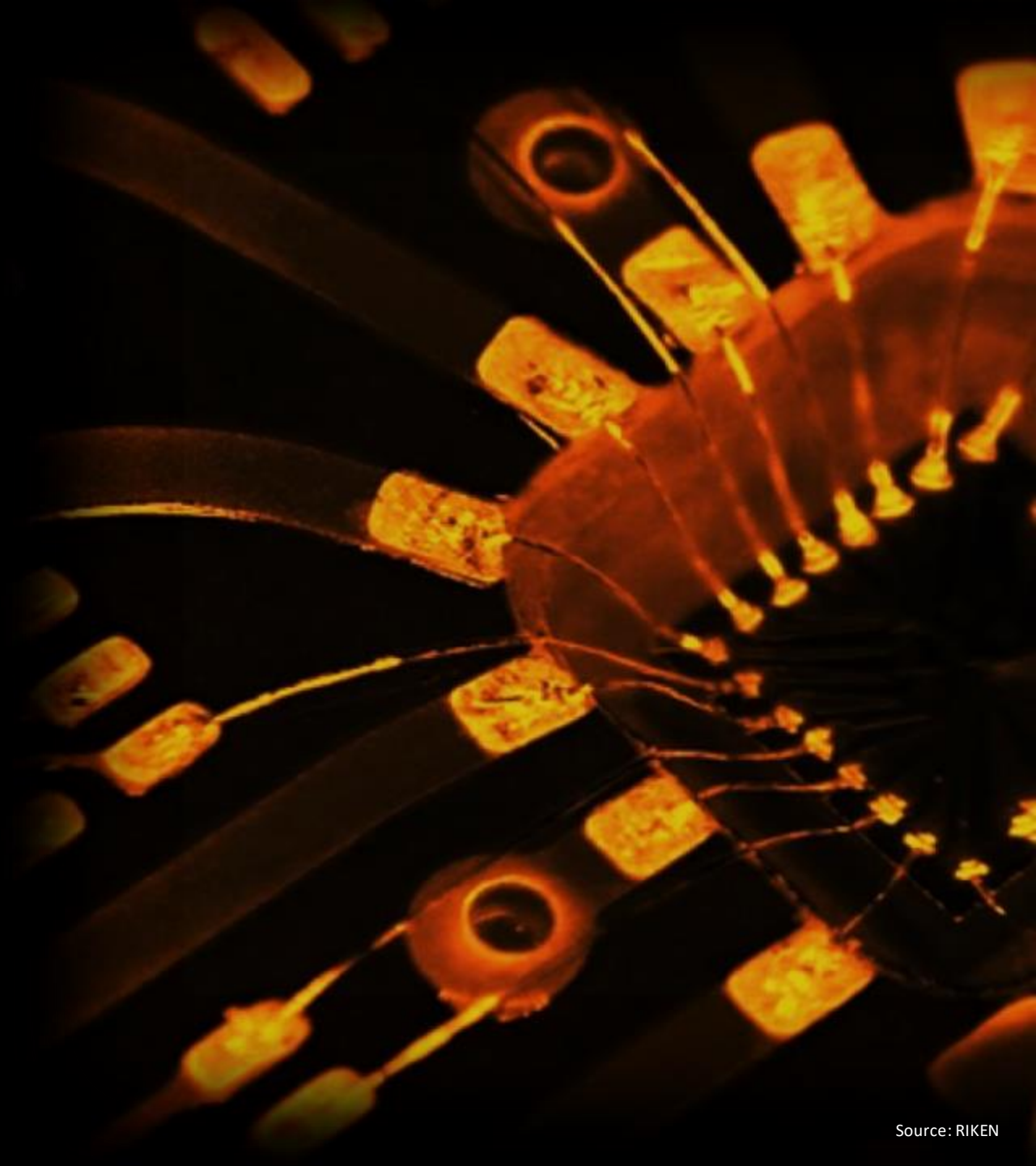# Agenda

1. Status on quantum computing

2. Use Case examples

3. Platforms

4. Q&A

Status on quantum computing

There are three possible roads to quantum computing

Gate Based Quantum Computing

- The ultimate goal of quantum computing

- Promises exponential improvement

- Hardware still in the early stages

Quantum Annealing

- Fewer vendors are supplying this hardware

- Brings advantage to a very specific set of problems (QUBO)

- More mature hardware, good for optimization, algorithms are used in production

Quantum Inspired Optimization

- Classical hardware simulates quantum annealing

- Exploits the maturity of classical hardware and cleverness of quantum algorithms

- Ready to use

Gate based Quantum Computer

- Exchanges the classical bit for qubits (quantum bits) – computation power doubles for every qubit

- Exploits quantum mechanical effects to for more efficient computations - promises exponential improvement compared to classical computers in some cases

- Hardware is still in early stages - the largest quantum computers has 127 qubits

- Faces engineering challenges due to noise

Photo from IBM Research
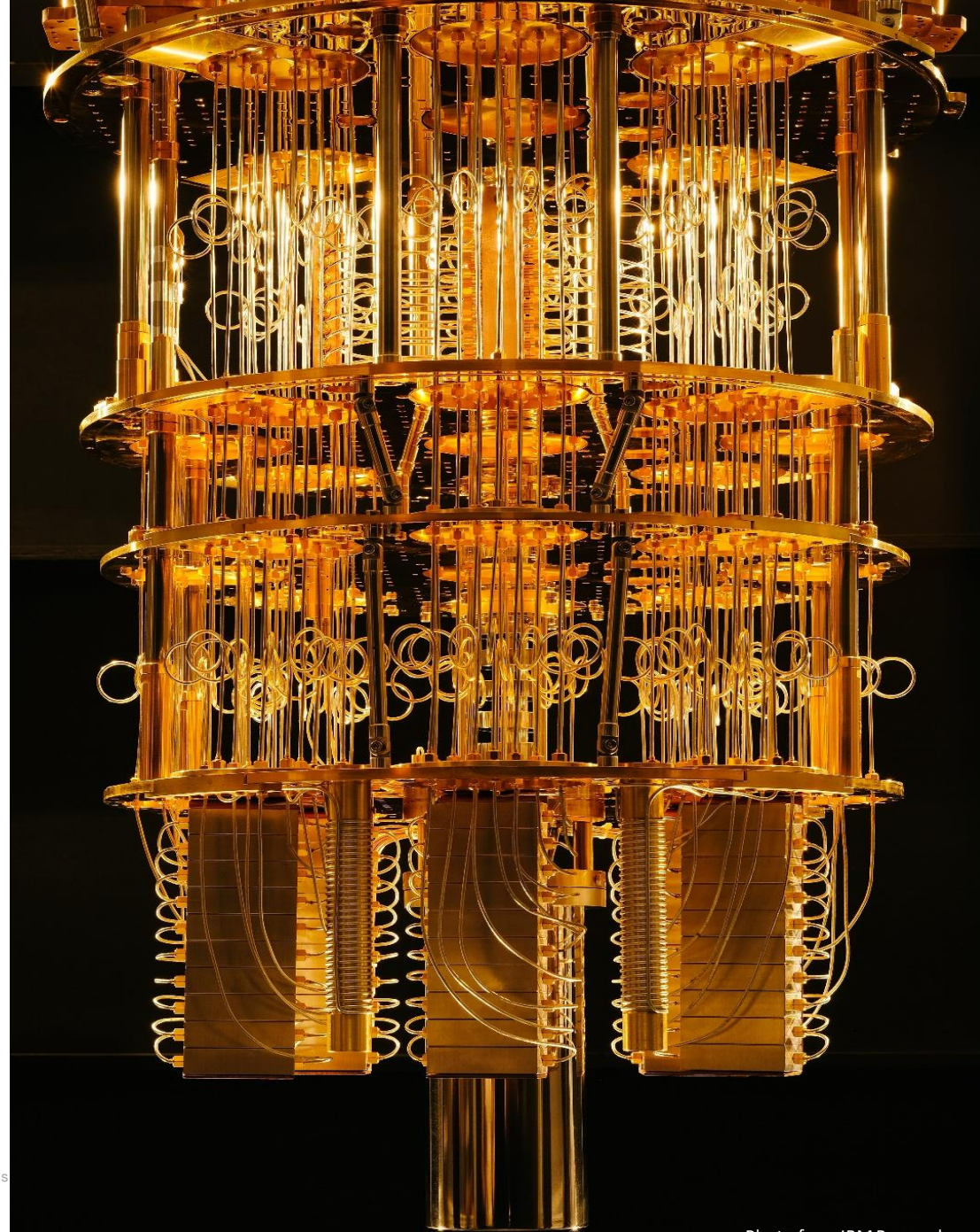
Quantum Computers are coming sooner than you think!

Investments

- Tech-giants such as IBM, Google, Microsoft and Honeywell are investing heavily in Quantum Computing.

Rapid Growth

- IBM has increased the size of their Quantum Computer from 27 to 127 qubits over the last two years – and are aiming for 1000 qubits in 2023. [2][3]

Not just bigger, but better

- Honeywell has made significant progress in 2021 demonstrating real-time quantum error-correction and achieved significant computational advantages. [4][5]

References:

[2] *IBM Quantum breaks 100 qubit mark*, IBM (2021)

[3] *IBM's roadmap for scaling quantum technology*, IBM (2020)

[4] *Realization of real-time fault-tolerant quantum error correction*, Ryan-Anderson, C. et. al. (2021)

[5] *Holographic dynamics simulations with a trapped ion quantum computer*, Chertkov, Eli et. al. (2021)

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One type of problem
can already be solved
by specialized quantum
computers ...

Source: D-Wave

Quantum Annealers solve QUBO optimization problems

Quadratic

Unconstrained

Binary

Optimization

QA can solve problems such as

- **Traveling salesman problems and vehicle routing problems**
- **Job-shop scheduling**
- **Portfolio optimization**
- **And many other highly combinatorial optimization problems…**

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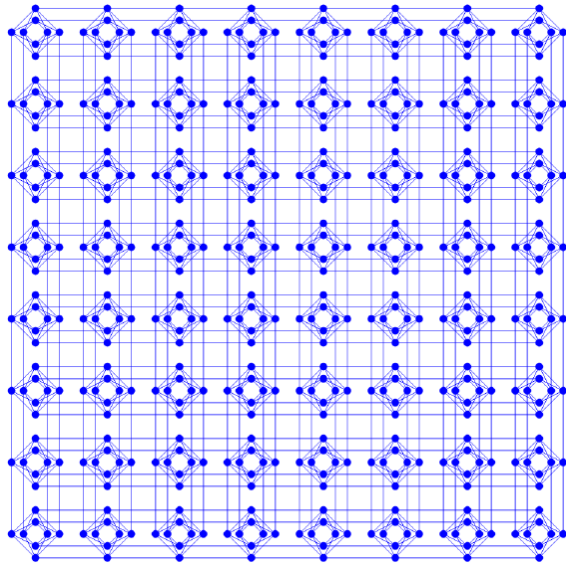
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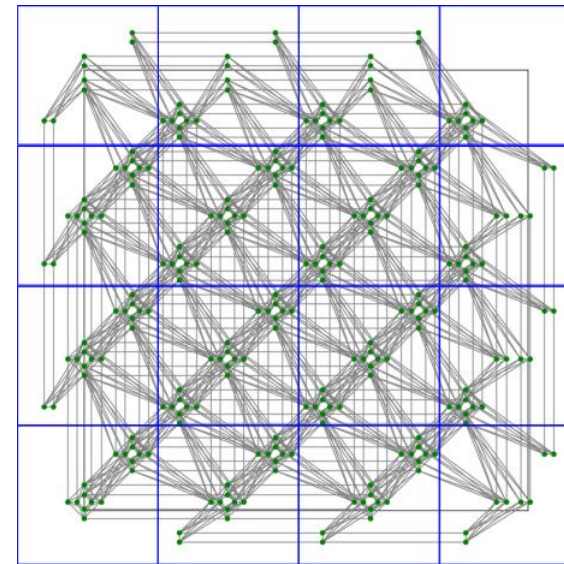
- Ready to use

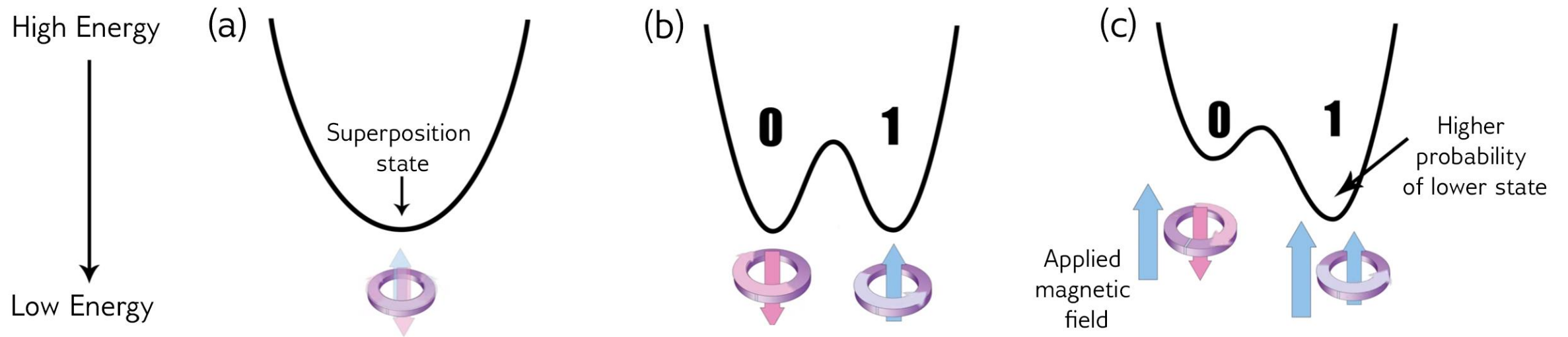# On D-wave you embed problems on quantum hardware

Chimera (old)

2000 Qubits
Nominal Length 4
Degree 6

Pegasus (new)

5000 Qubits
Nominal Length 12
Degree 15

... and slowly let the system discover the minimum value

High Energy

Low Energy

(a) Superposition state

(b) 0 1

(c) 0 1 — Higher probability of lower state

Applied magnetic field

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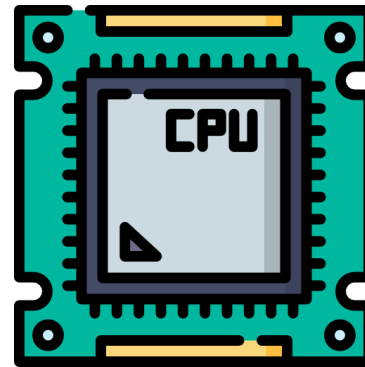
Quantum Inspired Optimization

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Quantum Inspired Optimization simulates Quantum Annealing using classical hardware

Tackles QUBO problems on a
variety of solvers

Hardware is mature

Can embed millions of
variables

Use case examples
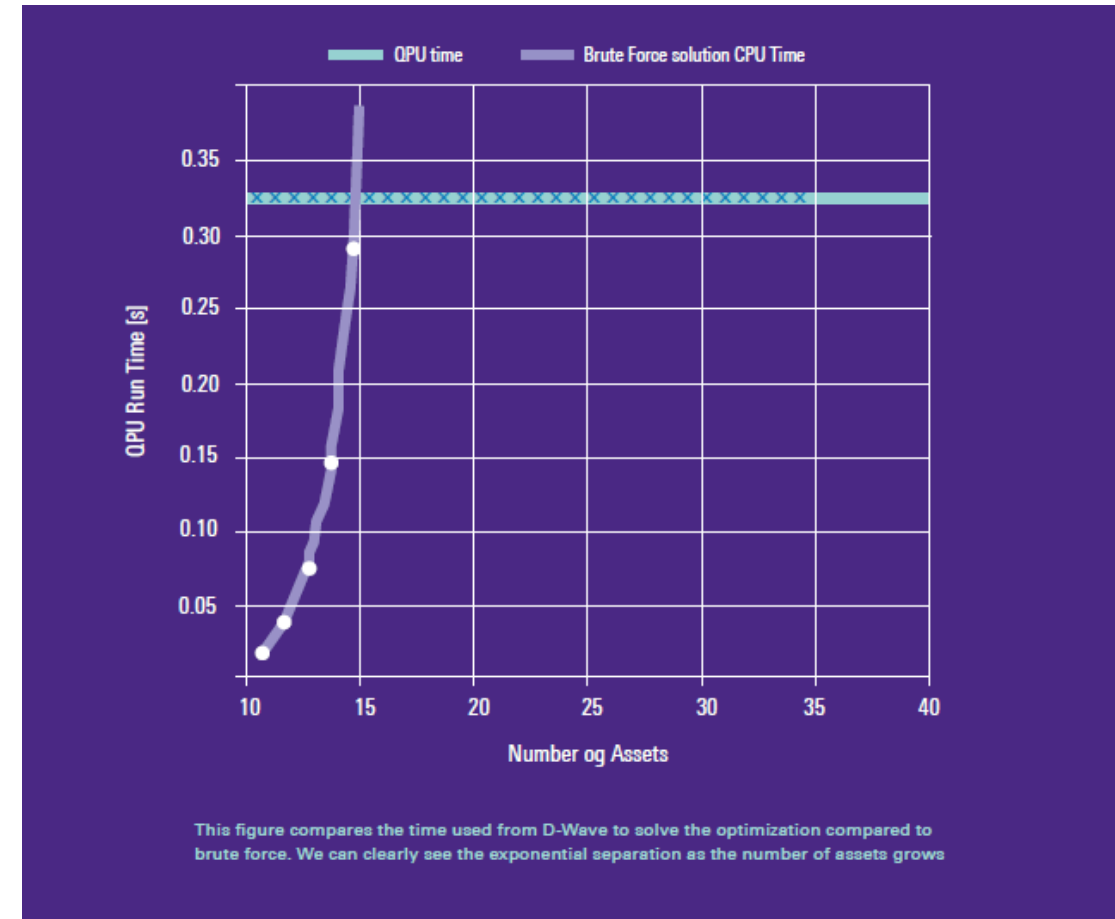
Traffic Route Optimization

- Projects for Volkswagen using D:Wave as hardware provider through Google optimizing routes for public transport and minimize traffic congestion.

- Traffic flow optimization for taxis in Beijing and real-time fleet-optimization for busses in Lisbon.

- App and algorithm currently being developed to market maturity

- KPMG is currently exploring business opportunities MS Azures demo fleet optimization tool
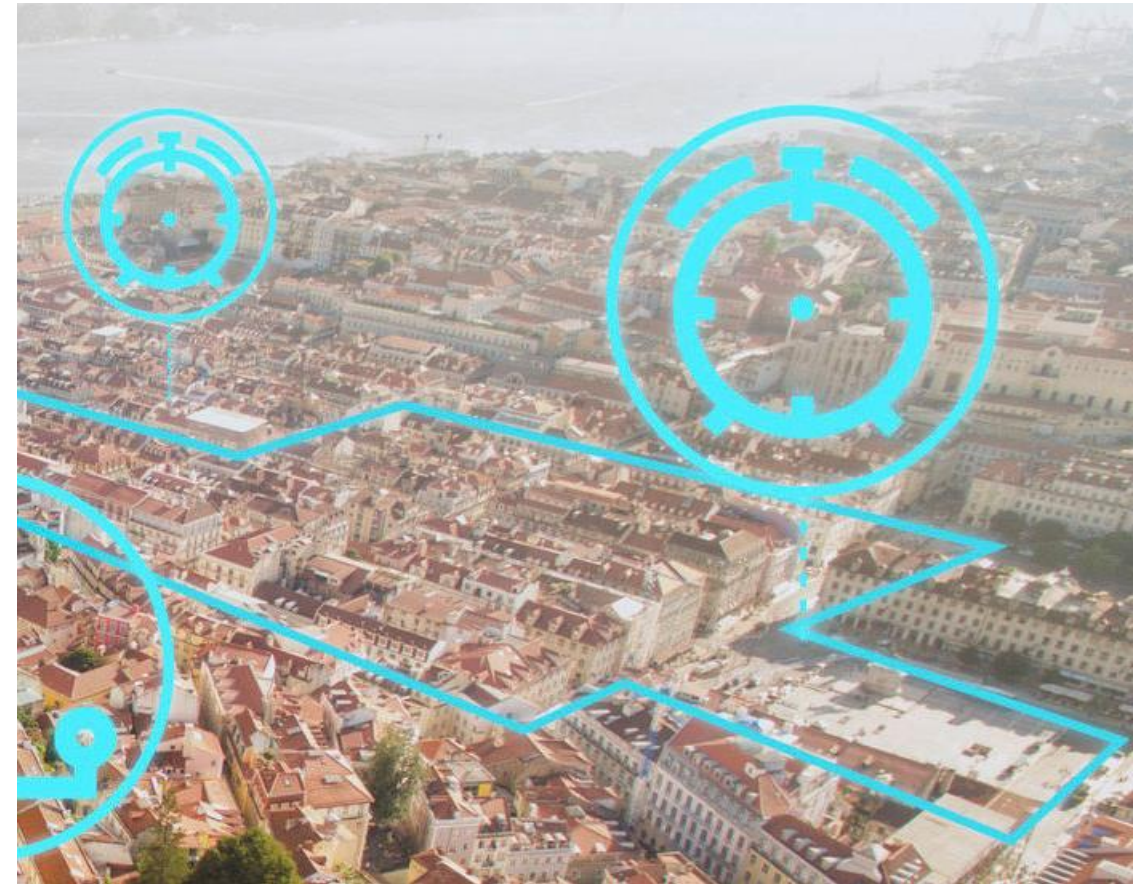
Source: Volkswagen

Portfolio Optimization

- Testing portfolio selection with quantum annealers on a portfolio with 65 shares

- Showed advantages compared to classical "brute force" computing methods for portfolios of up to 25 stocks

- Result are from 2000 qubit annealer and could be improved on newer hardware.

- KPMG is exploring this in a current financial service project

This figure compares the time used from D-Wave to solve the optimization compared to brute force. We can clearly see the exponential separation as the number of assets grows

mRNA codon optimization

- Reverse translation of polypeptide sequences to expressible mRNA constructs is a NP-hard combinatorial optimization problem.

- Quantum annealing shown to be competitive with genetic algorithm.

- Solutions to this problem are highly useful within drug discovery.
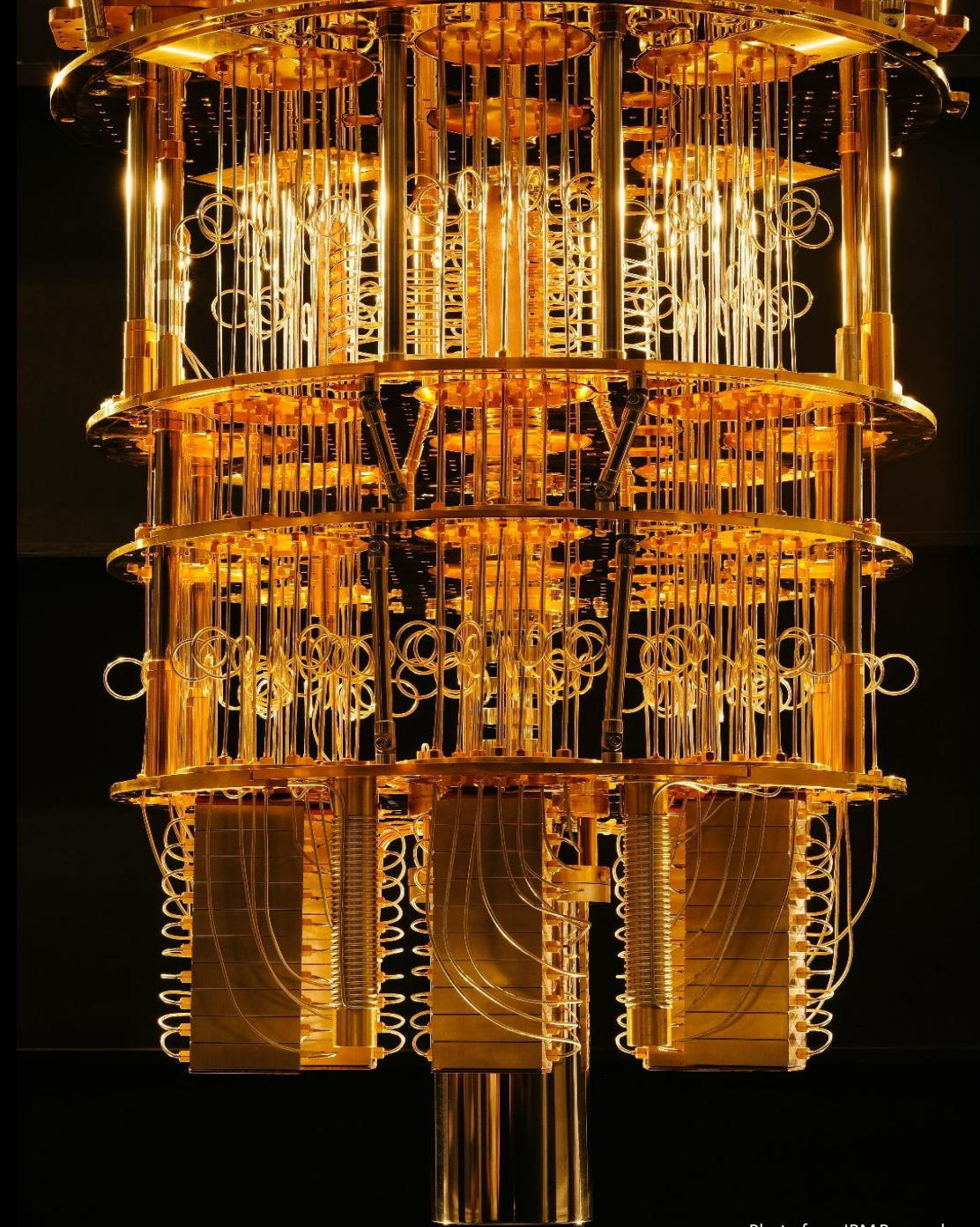
TIM improved 4G/5G networks

- Optimizing parameters on TIM's 4G and 5G network using quantum annealing.

- Showed to perform tasks 10x faster than conventional methods.

- Part of a close to real-time network configuration project.

- KPMG has a current project with a major provider optimizing placements of antennas

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Platforms

Quantum platforms available for experimenting

Microsoft Azure
Q#, Cirq

aws
Braket, PennyLane, Ocean

Google AI
Cirq, Tensorflow, OpenFermion

Q-CTRL
Qiskit, Cirq, Pyquil, Qutip

rigetti
Forest SDK (PyQuil, QVM, quilc)

IBM
Qiskit

XANADU
Strawberry Fields, PennyLane

D:Wave
Ocean

MULTIVERSE
Singularity SDK

Vendor / Hardware	Microsoft Azure	aws	D-WAVE	Google	IBM	XANADU	MULTIVERSE
IBM					✓		✓
IONQ	✓	✓		✓			✓
rigetti	✓	✓					✓
D-WAVE		✓	✓				✓
Google				✓			
QUANTINUUM	✓						
PASQAL	✓						✓
Microsoft	✓						✓
OQC		✓					
TOSHIBA	✓						✓
XANADU						✓	✓

Legend:
- Superconducting
- Ion
- Neutral atom
- Photonics
- Topological
- Annealing

Right now a quantum strategy is being made by the danish government...

Companies like JP Morgan, Goldman Sachs, Novo Nordisk, Vodafone and Volkswagen are currently experimenting with quantum computing...

Are you?

Q-uestions?

Thank you