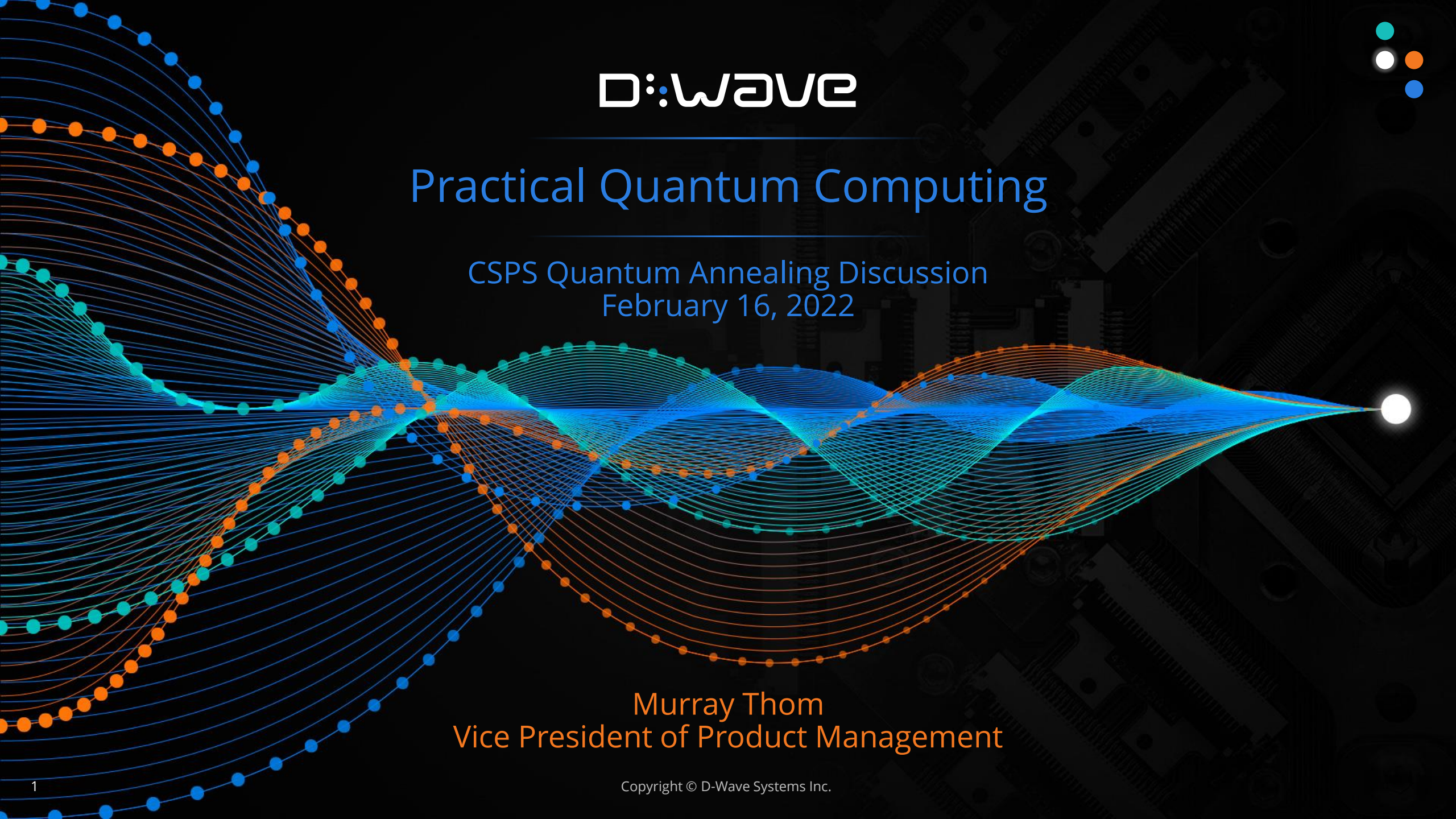


Practical Quantum Computing

CSPS Quantum Annealing Discussion
February 16, 2022

Murray Thom
Vice President of Product Management

Practical Applications Of Quantum Computing

Financial Services | **Scheduling & Logistics** | **Manufacturing & Mobility** | **Life Sciences / Materials Discovery**

The Future Is Now

You Are Here

PHASE 4 Quantum Advantage

PHASE 3 Customer Advantage

Theoretical Foundation Strengthened

PHASE 2 Speedup on Physics Problems

PHASE 1 Speed-Up On Benchmark Problem

The past 20 years

Quantum computing is highly theoretical, impractical and only available to a small group within the scientific community

100x speedup over best classical heuristics

3Mx speedup over best classical heuristics

Professional services go-to-market yielding business applications running in production with demonstrated ROI

- Menten **100x** speedup
- Save-on-Foods **500X** speedup
- VW **80%** waste reduction

250+ Early Applications

Quantum computers demonstrate absolute advantage on real world problems

D-Wave 2000Q

D-Wave 2000QLN

Leap

Hybrid Solver Services, Real Time Access, IDE, Community

Advantage

Advantage Performance, 2, 3...

Gate Model

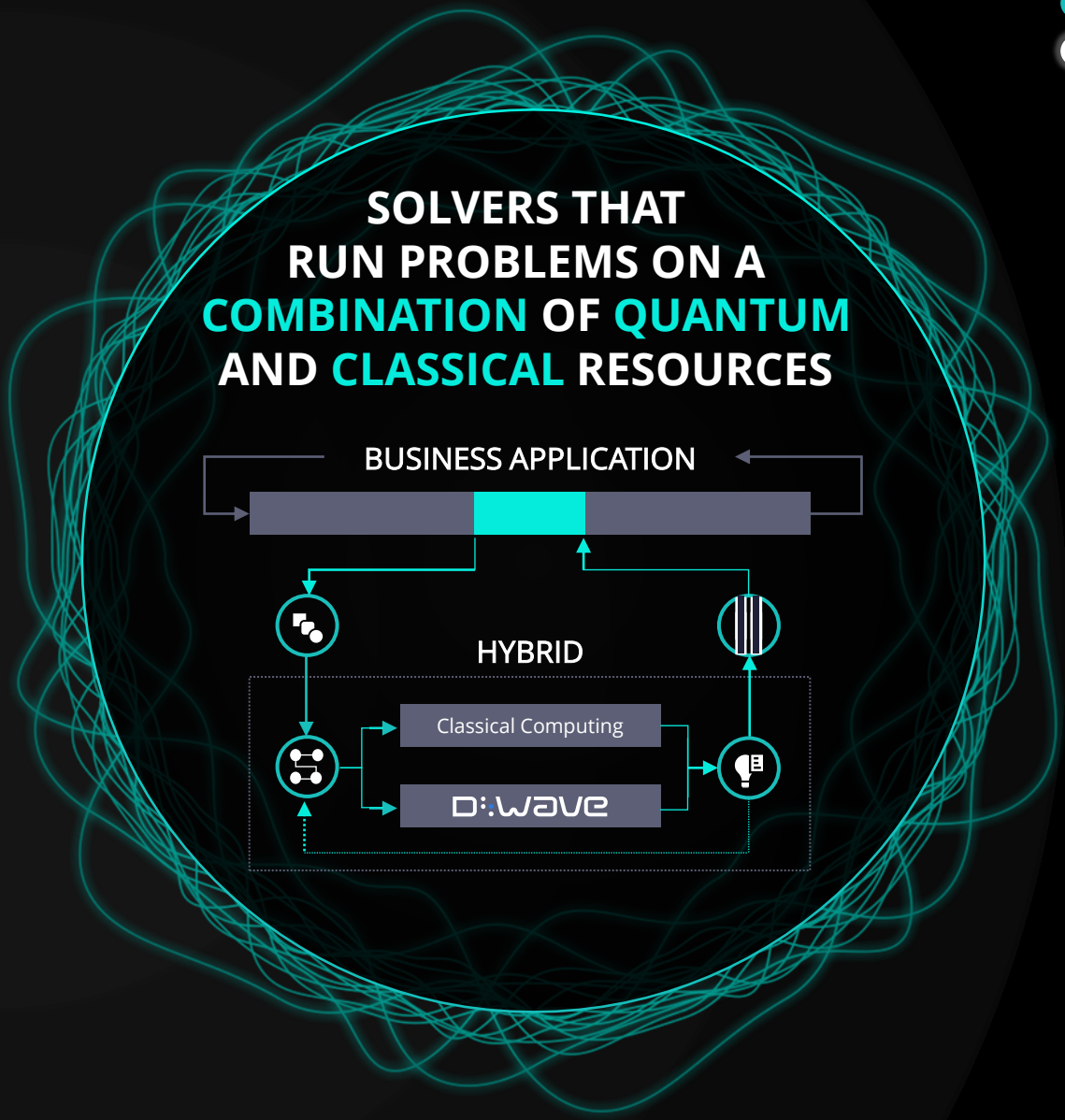
Powerful Hybrid Solvers

Constrained quadratic model solvers

- More native representation of problem
- Unlocks larger application problems
- Up to 100,000 constraints
- Inequality & equality constraints

Binary quadratic model solvers

- Up to 1,000,000 variables
- Enables enterprise-scale problem solving
- Accepts problems with binary variables



D-Wave *Clarity* Roadmap

2021 | 2022 | 2023 | 2024 | 2025+

advantage
Quantum Systems

Annealing

- Performance updates and ever lower-noise investments
- Advantage 2: New qubit design
- Focused growth in qubit connectivity

Gate

- **Multi-Phased approach to an error-corrected, scalable, gate-model system:**
  - Validate qubits in multilayer stack | Validate on-chip control | Validate error correction
  - Demonstrate logical qubit manipulation | Design scalable task-specific components

Leap
Quantum Cloud

- Native problem formulations
- Cross-platform Ocean tools
- Gate-model simulators and application templates
- Cross-platform solvers
- QPU Integration
- Enabling ISVs and partners

Ocean
Developer Tools

- Running global customer in-production applications at scale

Application Domains

- Logistics & Scheduling
- Patient Trial & Manufacturing Optimization
- Risk Management
- 5G/IoT/ Wireless
- Drug Discovery

Quantum Use Cases in Financial Services

- Dynamic Portfolio Optimization
- Trading Optimization
- Risk Management
- Risk Profiling
- Market Correction Prediction
- Currency Arbitrage
- Fraud Detection
- Product Offers and Recommendations

"Integrating the fundamentals of quantum mechanics into computer science will bring about a sea change in the depth and breadth of computing power."

BBVA

MULTIVERSE

BBVA accenture Bankia

Quantum Use Cases in Manufacturing, Logistics, and Mobility

- Paint Shop Optimization
- Grocery Store Logistics
- Sustainable Cities: Waste Collection
- Traffic Routing
- Traffic Signal Optimization
- Airline Scheduling/Planning, Routing
- Train Platforming Problem
- Supply Chain Optimization
- Staff Scheduling
- Logistics/Material Flow/Pallet Loading Optimization
- Electric Car Charging Station Optimization
- Port Scheduling and Planning

"To actually use the power of quantum computing is eye-opening, and it gives us a better understanding of the areas where we can harness that power to greater advantage"

—Tadashi Kadowaki, Manager, Quantum Computing & AI - DENSO

DENSO save on foods Groovenauts TOYOTA

Optimize Automated Guided Vehicles on Factory Floors

Production Inefficiencies

Vehicle control, collision avoidance, and production lines can all be streamlined

Streamlined Vehicle Flow

D-Wave's system reduced AGV waiting time by over 15%

Optimize Flight Gate Assignment to Minimize Total Transit Time

Business Impact:

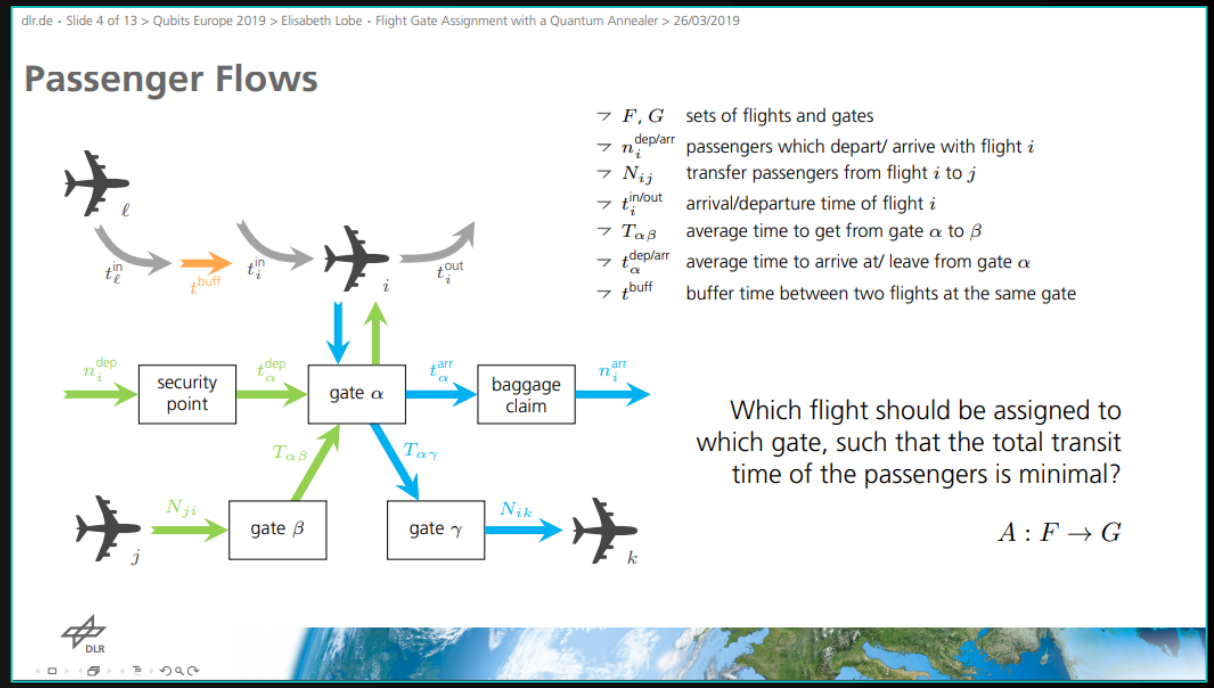
A typical day at the Frankfurt Airport involves coordinating the real-time movements of hundreds of aircraft carrying more than 170,000 passengers between 278 gates. This results in excess travel time and increased costs for businesses and passengers.

D-Wave Solution:

DLR (Federal Republic of Germany's research center for aeronautics and space) used D-Wave technology to address this challenge by constructing the problem as a QUBO (quadratic unconstrained binary optimization) problem.

Business Value:

The team found that the flight gate assignment problem is very well suited for D-Wave and quantum annealing.



DLR

Streamline the Automotive Supply Chain for Efficiency Gains

Paint Color Switches

Auto manufacturer incurred high costs and waste due to numerous paint color switches in assembly line

80%
Reduction in Waste

5x More Efficient

Using the D-Wave Hybrid Solver Service, the manufacturer can now paint 5x more cars per color switch

"This application has immediate, real-world implications for production and logistics."

—Volkswagen quantum researcher Sheir Yarkoni.

Create Sustainable Cities: Waste Collection Optimization

Business Impact:

Truck routes for waste collection are not optimized and result in excess vehicles, waste, and CO2 emissions.

D-Wave Solution:

Groovenauts and Mitsubishi Estate used a D-Wave system to optimize truck routes for waste collection, reducing total distance travelled from 2,300 km to just 1,000 km.

Business Value:

CO2 emissions reduced by approximately 57%, and the number of vehicles reduced by approximately 59%.

"Utilizing quantum annealing, the route for collecting waste, currently requiring a distance of about 2,300 km, was optimized and reduced to just 1,000 km. As a result, CO2 emissions would be reduced by approximately 57%, and the number of vehicles reduced by approximately 59%."

—From: Using Artificial Intelligence (AI) and Quantum Computers for Optimized Waste Collection and Transport Verified in Reduction of CO2 Emissions

Groovenauts

MITSUBISHI ESTATE

Applications in Life Science

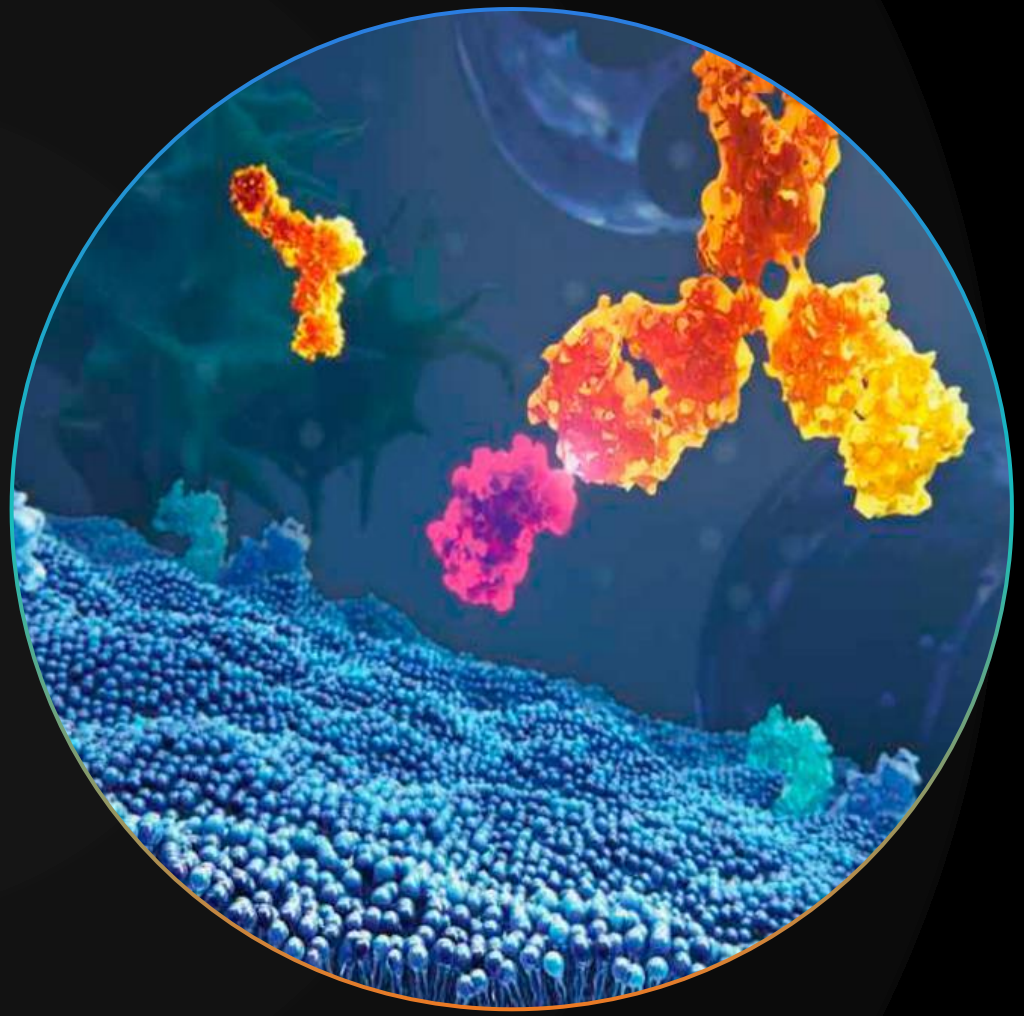
Pharma: from discovery to approval

- Lead generation: Protein design for drug and enzyme discovery
- Preclinical research: Feature selection and machine learning
- Clinical development: Clinical trial selection and optimization

Medical imaging & image analysis

Sensitive/early disease detection

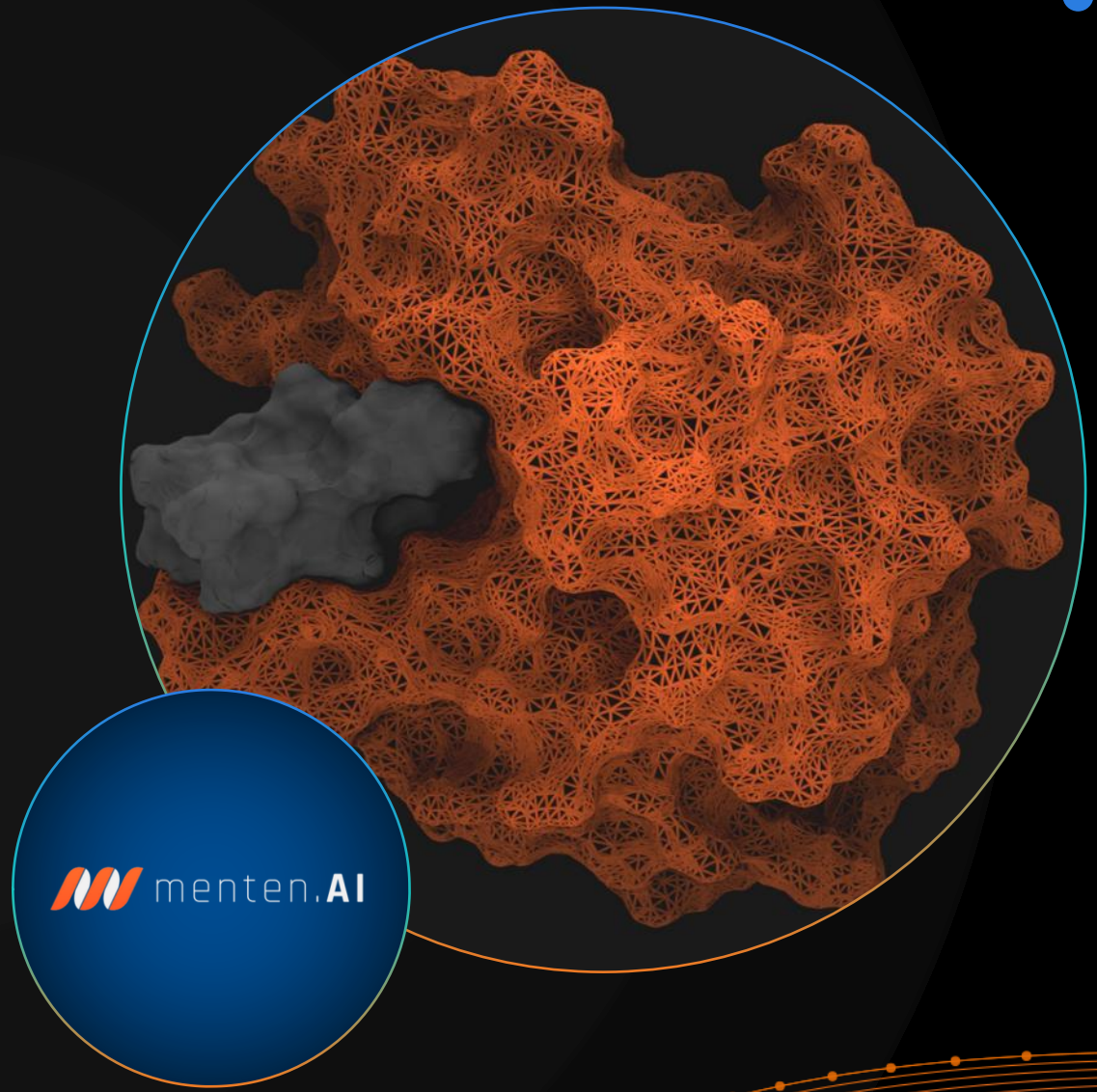
Genomics



Protein Design

Menten AI has built an application to design peptides using D-Wave hybrid computing system:

- Identify the target and objective: e.g. increase binding efficiency
- Create a sequence that fits the substrate (e.g. using molecular dynamics)
- Optimize the sequence using D-Wave hybrid solver service through Leap
- Verify solution by protein folding simulations
- Synthesize and verify structure
- Currently: live-virus testing



Quantum-classical hybrid computing enables:

- Optimization of large sequences
- Faster production of design candidates

Quantum Annealing to Accelerate Codon Optimization

Business Impact:

Classical computing uses genetic algorithms (GAs) that sample and iterate many different combinations of codons before settling on the most "optimal" solution. GA's are limited and cannot sample a large number of solutions in little time, which results in long drug discovery cycles.

D-Wave Solution:

D-Wave's Leap Hybrid solver is (theoretically) capable of solving codon optimization problems expressed as a BQM with up to ~1,000 amino acids, while Advantage could run up to 30 amino acids. It was found to achieve similar results when compared to the classical algorithms.

Business Value:

As the technology increases in scale, the researchers expect it to eventually outperform classical techniques on life-sized problems.

"[D-Wave] is found to be competitive in identifying optimal solutions, and future generations may be able to outperform classical GAs."

—GSK Researchers

gsk
GlaxoSmithKline

Defence Use Cases

Australian Army resupply by autonomous ground vehicles

- Demo: https://youtu.be/Z4Xq5DPFJFI

GE Research's quantum annealing for asset sustainment

- https://www.dwavesys.com/media/prsl42qn/ge-research-asset-sustainment-2019-qubits-europe_0.pdf

Threat detection in graphs using quantum computing to calculate vertex covers by Ridgeback Network Defense

- https://www.dwavesys.com/media/gtklt3bn/threat-detection-in-graphs-using-quantum-computing-to-calculate-vertex-covers.pdf

Emergency Response

IEEE on COVID response on Tsunami Evacuation Optimisation

- https://spectrum.ieee.org/can-quantum-computing-help-us-respond-to-the-coronavirus

Pandemic Schedule with Sigma-i

- https://www.dwavesys.com/media/1orcfue1/sigma_personnel-management-_case_story_v2-2.pdf

Enabling Quantum Computing for Material Discovery

- https://otilumionics.com/quantum-computing/

https://www.dwavesys.com/learn/resource-library/

Quantum Computing – For Today's Military

Advanced Technology Academic Research Center (ATARC) - Applied Quantum computing for Today's Military White Paper

- Simulations
- Radio Frequency & Satellites
- Logistics & Supply Chain Optimization
- Energy Management
- Predictive Maintenance
- Autonomous Vehicles
- Emergency Response

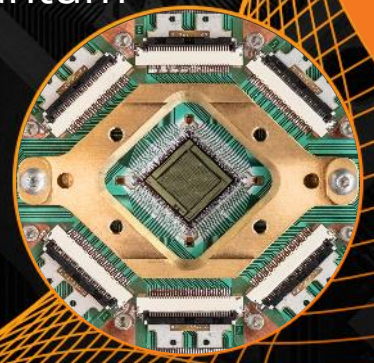
https://atarc.org/wp-content/uploads/2021/05/ATARC-Military-Paper-by-Quantum-Working-Group.pdf

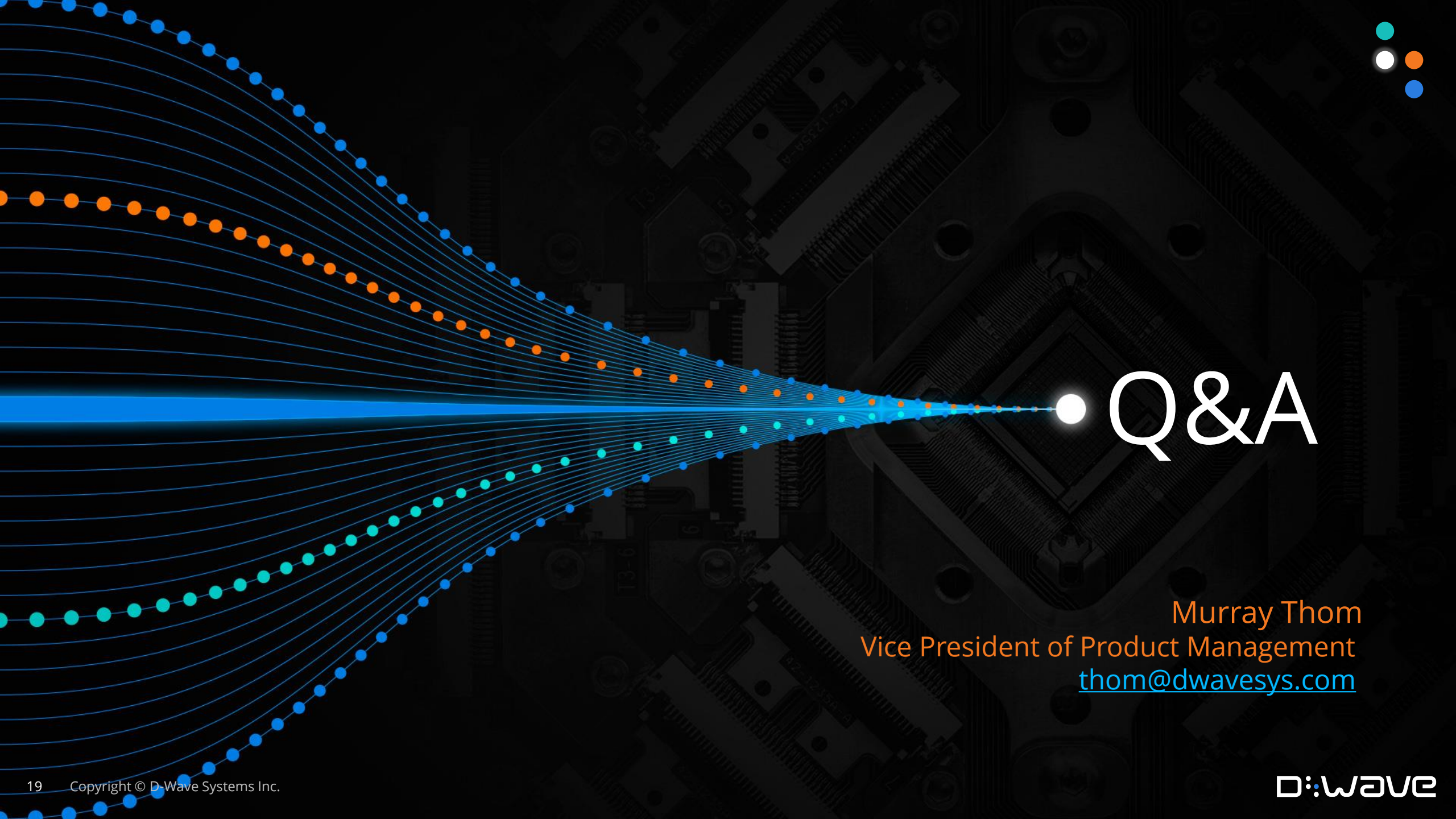
DEMO

About D-Wave

- First commercial provider of quantum computing, 20+ years in business.

  10+ years commercializing quantum systems.
- Full stack systems, software and services provider
- 15-way connectivity
- The Advantage™ quantum system available via the Leap™ quantum cloud service with 5000+ qubits, is online for solving complex computing problems
- Over 250+ early applications
- 200+ patents granted
- Developed and released 5 generations of quantum systems, doubling the number of qubits in successive generations.





Q&A

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