

# GOTO Copenhagen 2021

**#GOTOcph**



# Unboxing Quantum Computing

Murray Thom, VP Product Management  
GOTO Copenhagen, 2021 Nov 8



# Over 250 Early Applications Across Multiple Industries



BBVA

save on foods



Menten AI

Financial Services

Scheduling & Logistics

Manufacturing & Mobility

Life Sciences / Materials Discovery

# 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.



# Business-Critical Tasks in Minutes Instead of Hours



## Productivity Loss

Grocery chain was spending 25 hours a week on operational optimization tasks

**save on foods**

**25 Hours to 2 Minutes**  
to Complete Business Critical Optimization Tasks

## 500x Speedup

With D-Wave Hybrid Solver Service, the company replaced classical approaches and saw a 500X speedup

*"D-Wave gives us the ability to seamlessly integrate quantum into our business problems."*

—Save-on-Foods

# Optimize Automated Guided Vehicles on Factory Floors



## Production Inefficiencies

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



***DENSO***

Efficiency Gains,  
Reduced Manufacturing  
Congestion, and  
Time Savings

## Streamlined Vehicle Flow

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



# Why Quantum Computing

## Enormous *potential* speed-up

- Referred to as super-exponential

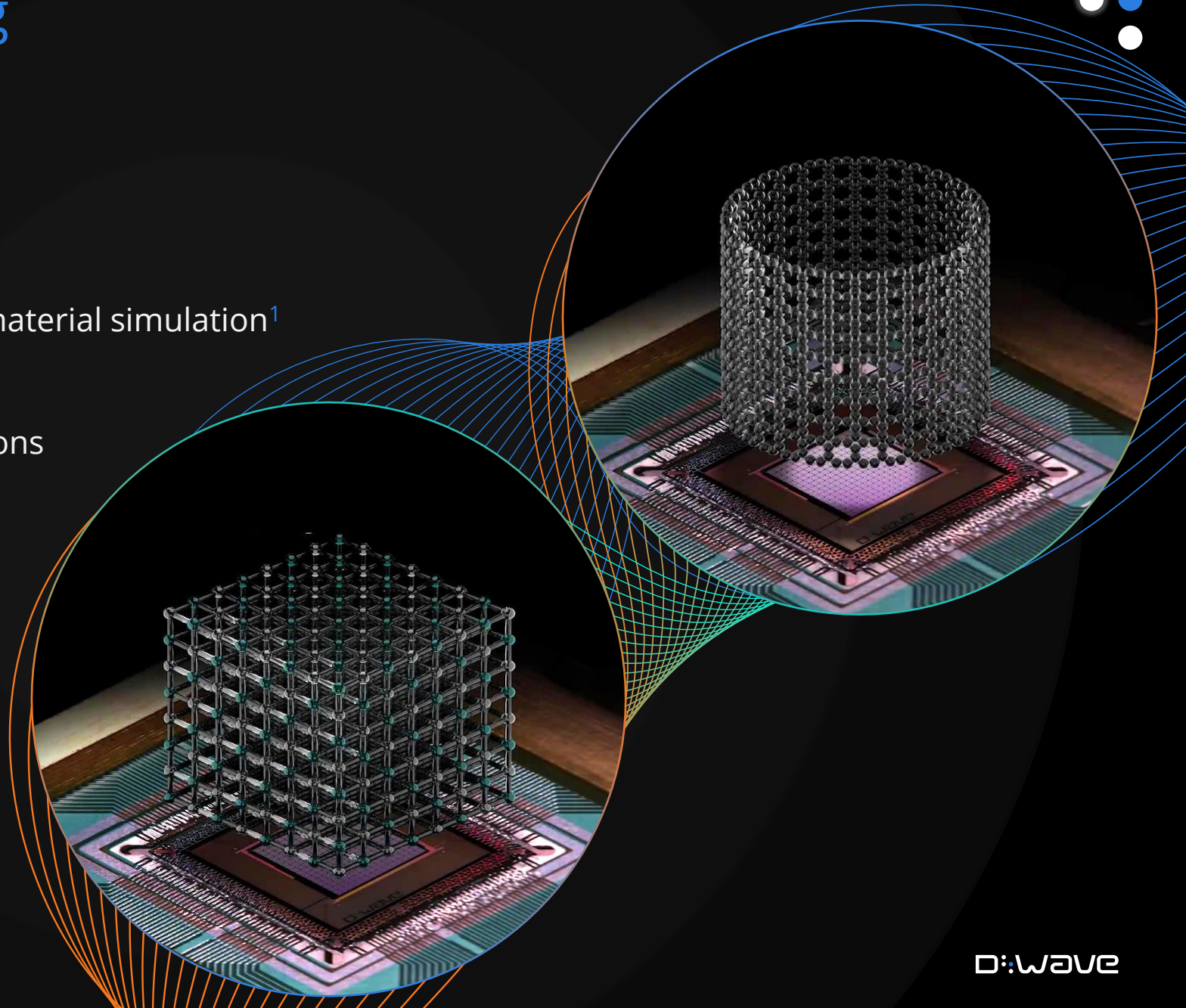
## Observed speed-ups so far

- 3,000,000X in applications of quantum material simulation<sup>1</sup>

## Real world applications

- 100X-500X in early commercial applications

<sup>1</sup>King, A.D., Raymond, J., Lanting, T. *et al.* Scaling advantage over path-integral Monte Carlo in quantum simulation of geometrically frustrated magnets. *Nat Commun* **12**, 1113 (2021).  
<https://doi.org/10.1038/s41467-021-20901-5>



# Quantum Computing Total Addressable Market

## D-Wave is the Solution of Choice for Optimization Problems

Short, medium, and long term, annealing will dominate the optimization space in quantum computing.

Value of \$5 billion to \$10 billion should start accruing to users in the near to mid term (BCG).



Source: Boston Consulting Group: "Where Will Quantum Computers Create Value – and When?" May 2019 (80% of TAM accruing to end-users; 20% to quantum hardware, software and services providers)



# Better Together: A Comprehensive Platform



## THE QUANTUM COMPUTER BUILT FOR BUSINESS

New processor

Larger + more complex problems

5,000+ qubits

15 way connectivity

Performance updates  
available in Leap Today!



## THE QUANTUM CLOUD SERVICE BUILT FOR BUSINESS

Immediate access

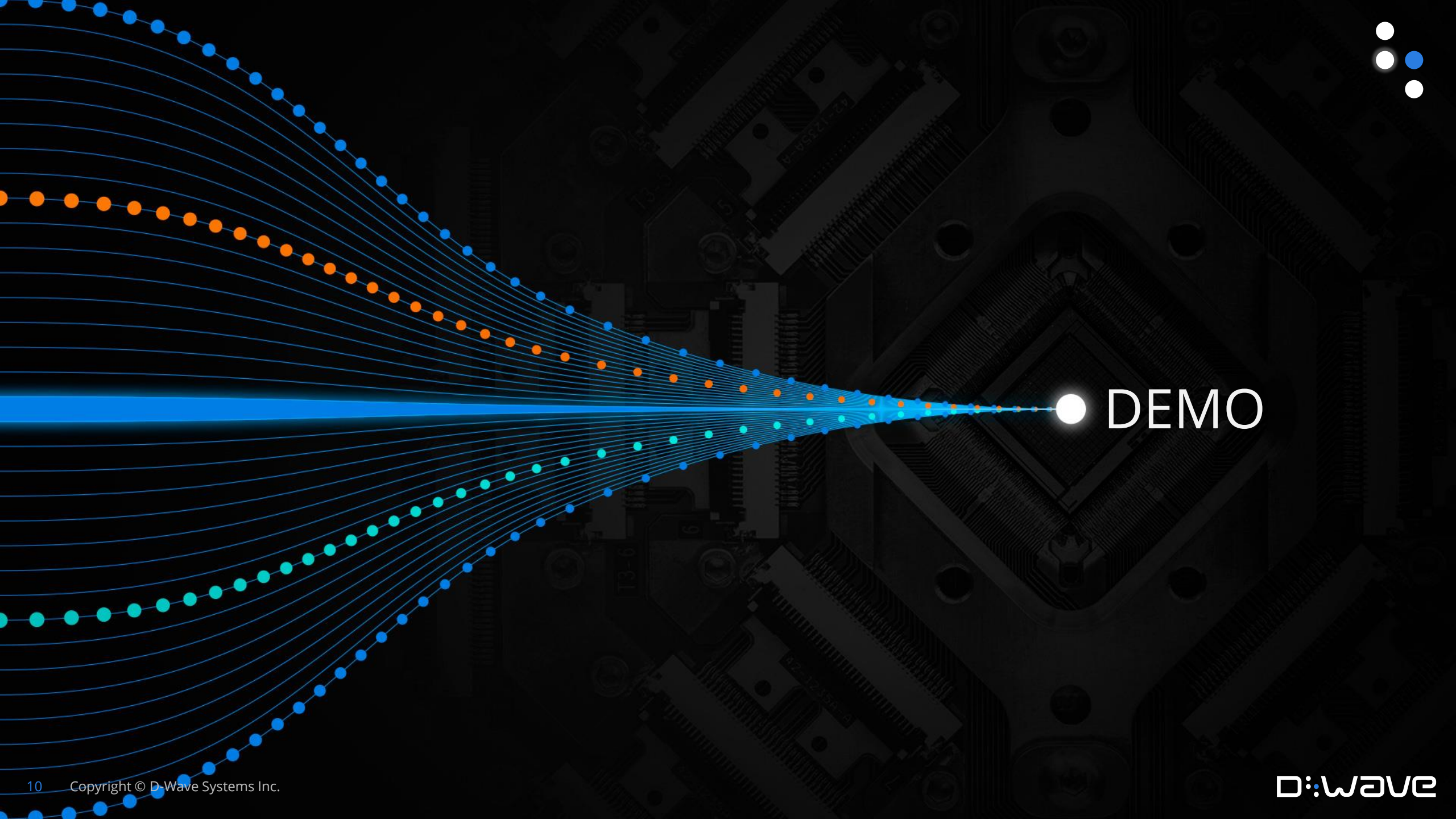
Integrated IDE

1 million variable hybrid solver

Collaboration

All new Constrained  
Quadratic Model solver!





DEMO



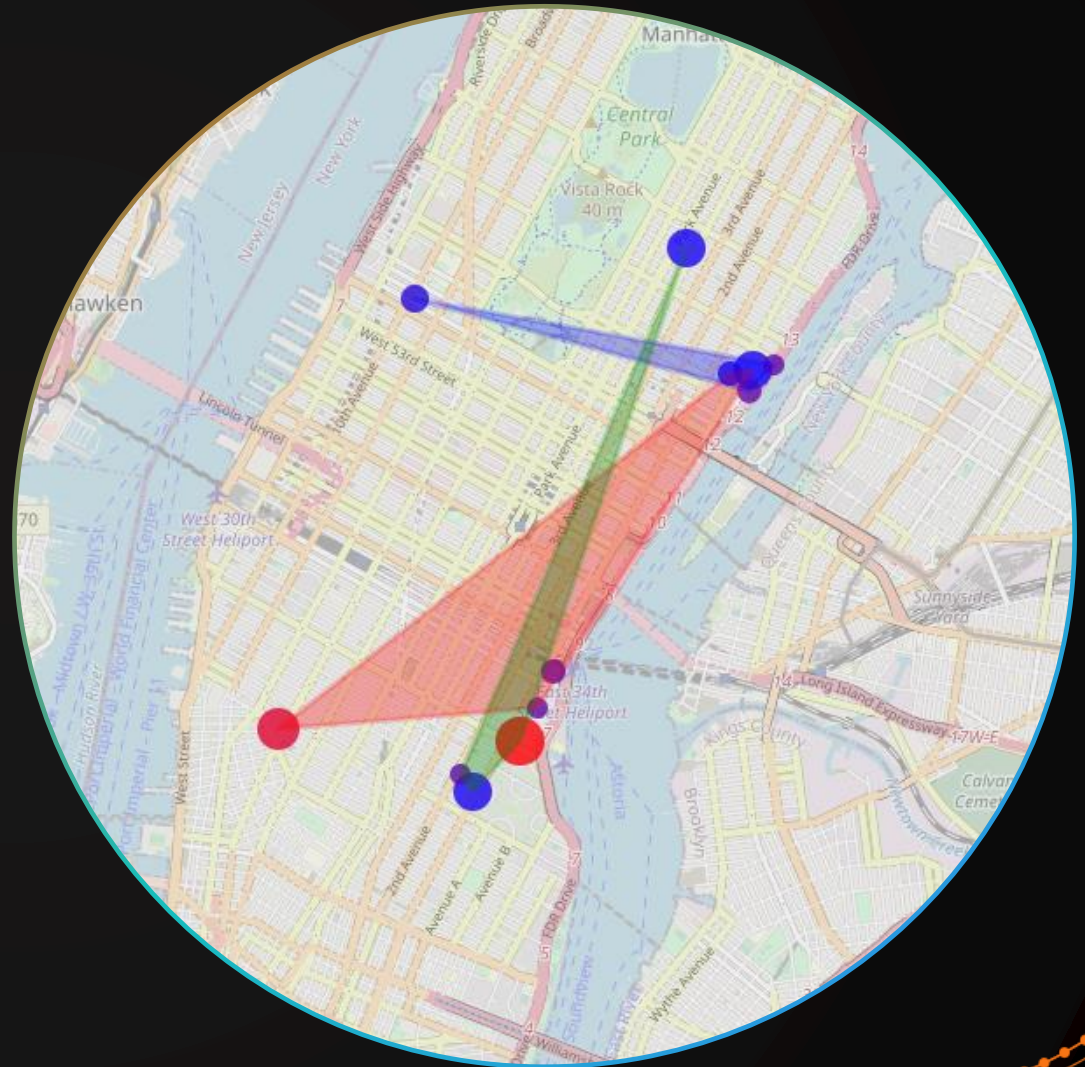
# Hospital Allocation with Constrained Quadratic Models

## Given

- Hospital locations
- A surplus or shortage of beds, per hospital
- A transfer cost between hospitals

## The problem

- Assign each hospital to a group
- Each group must have a net surplus of beds
- Minimize the total cost of transfers



# Hospital Allocation with Constrained Quadratic Models

1. Create binary variables matching each hospital to a group.
2. Enforce that no hospital can be in more than one group.

```
for hospital in hospitals:  
    cqm.add_discrete([(hospital, group) for group in range(num_groups)])
```

3. Enforce that each group must have a net surplus of beds.

```
for group in range(num_groups):  
    cqm.add_constraint(sum(variables[hospital, group]*beds for hospital, beds in hospitals.items()) >= 0)
```

4. Minimize the total cost of transfers

```
objective = 0  
for hospital1, beds1 in hospitals.items():  
    for hospital2, beds2 in hospitals.items():  
        if beds1 > 0 and beds2 < 0:  
            for group in range(num_groups):  
                objective += variables[hospital1, group]*variables[hospital2, group]*distances[hospital1, hospital2]  
cqm.set_objective(objective)
```

5. Solve on the Hybrid Solver Service (HSS)

```
sampleset = LeapHybridCQMSampler().sample_cqm(cqm)
```



# Built for In-Production Applications

## Advantage Access Today:

- Developers, businesses and new users have access to the most connected and powerful quantum computer built for business

## Real-Time Cloud Access:

- Open-source Ocean tools and examples
- Online IDE and interactive visualization
- Hybrid solvers adapted to the latest QPU technology and improving with ongoing algorithm development
- Online training and resources



```
maximum_cut.py x
# Run the QUBO on the solver from your co
49 sampler = EmbeddingComposite(DWaveSampler(soc
50 response = sampler.sample_qubo(Q, chain_strength
51 energies = iter(response.data()))
52
53 # ----- Print results to user -----
54 print('-' * 60)
55 print('{:>15s}{:>15s}{:>15s}{:>15s}'.format('Set 0', 'Set 1
56 print('-' * 60)
57 for line in response:
58     S0 = [k for k,v in line.items() if v == 0]
59     S1 = [k for k,v in line.items() if v == 1]
60     E = next(energies).energy
61     print('{:>15s}{:>15s}{:>15s}{:>15s}'.format(str(S0), str(S
62
63 # dwave.inspector.show(Q, response)
64
65 # ----- Display results to user -----
66 # Grab best result
67 # Note: "best" result is the result with the lowest energy
68 # Note2: the look up table (lut) is a dictionary, where th
69 # and the value is the set label. For example, lut[5]
70 # node 5 is in set 1 (S1).
```

```
kspace/maximum-cut x
kspace/maximum-cut $ python maximum_cut.py
```



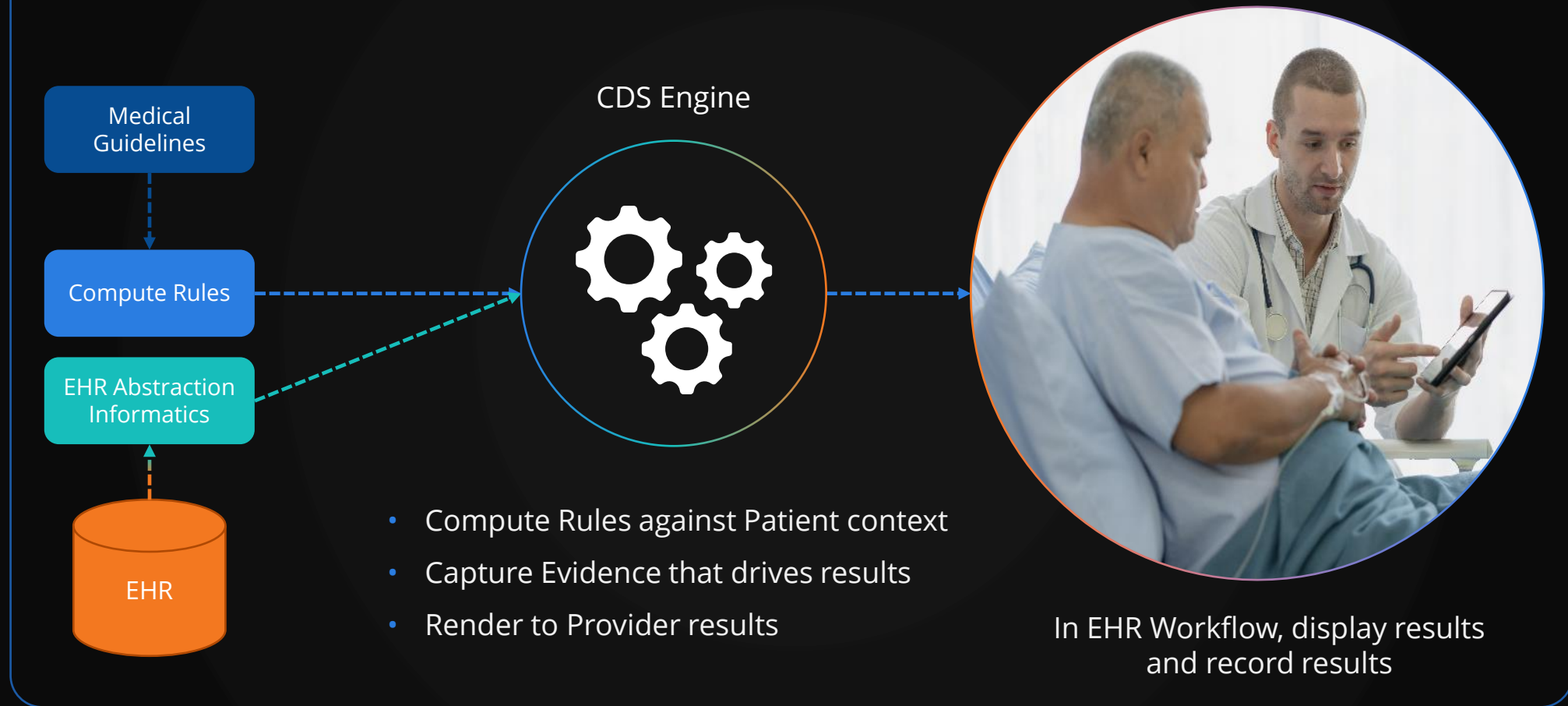
# Application Workflows



# Consider a Clinical Decision Support System



## BASICS OF KNOWLEDGE BASED CDS SYSTEM



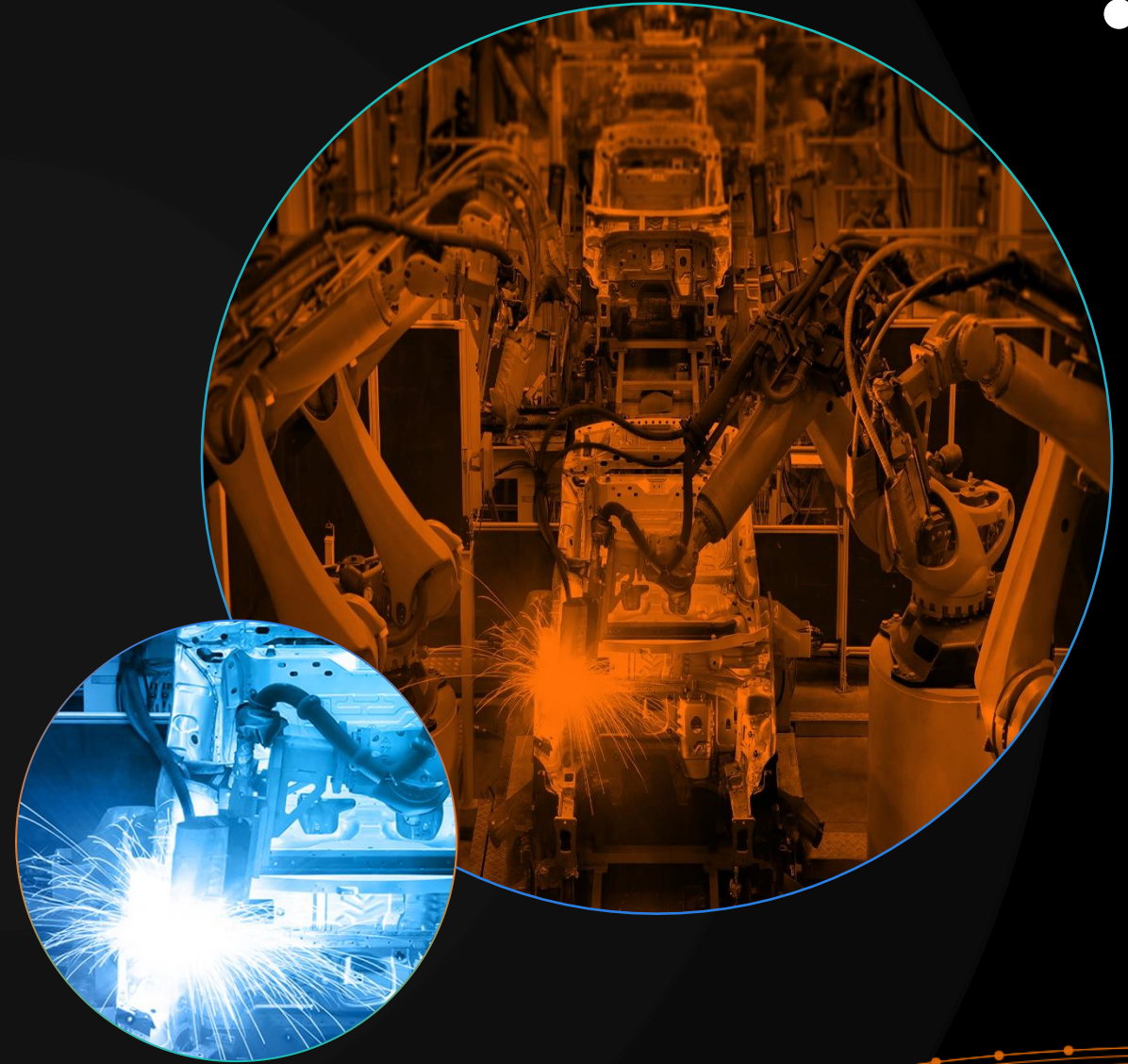
# Workforce Scheduling

## Operations scheduling

- Centralized scheduling
- Distributed expertise in machine operation
- Solution structure follows business process

## Class scheduling

- Centralized scheduling
- Distributed preferences informing constraints
- Wide variations, frequent changes





# Find Optimization Methods With Open Code Examples

## Variable encodings, selecting options

- Sudoku
- N-Queens

## Assignment to a group

- Graph colouring
- Cell tower frequencies

## Network coverage

- Min Vertex Cover
- Satellite Placement

## Interacting elements

- Maximum Independent Set
- Portfolio Optimization

The screenshot displays the D-Wave Leap website's search interface for code examples. The header includes the D-Wave Leap logo and navigation links: Dashboard, IDE Workspaces, Resources, Community, and Help. A user profile for Murray Thom is visible in the top right. The main section is titled "Search D-Wave's Collection of Code Examples" and features a search bar with the placeholder "Search examples...", along with filters for Industry, Application Type, and Techniques. Below the search bar is a "Clear Search & Filters" link. The results section shows "Showing 1 - 36 out of 36" items, sorted by "Relevance". A grid of example cards is displayed, each with a title, description, tags, and a star rating. The examples include: RNA Folding (3 stars), Reservoir Management (2 stars), Simple Ocean Examples (7 stars), Structural Imbalance in Signed Social Networks (18 stars), Sudoku (15 stars), Satellite Placement (10 stars), Portfolio Optimization, Multi-Car Paint Shop Optimization, and N Queens.

Example Title	Description	Tags	Stars
RNA Folding	Finds the optimal stem configuration of an RNA sequence using the LeapHybridCQMSampler.	HYBRID SOLVER	3
Reservoir Management	Manage water levels in a reservoir by controlling water pumps.	HYBRID SOLVER	2
Simple Ocean Examples	Examples of introductory Ocean programs and concepts.		7
Structural Imbalance in Signed Social Networks	Demo for analyzing the structural imbalance on a signed social network.	DEFENSE, OPTIMIZATION	18
Sudoku	Solve a Sudoku puzzle with a quantum computer.	HYBRID SOLVER, CONSTRAINT SATISFACTION PROBLEM	15
Satellite Placement	Group satellites into constellations such that their average observation coverage is maximized.	DEFENSE, AEROSPACE, OPTIMIZATION, HYBRID SOLVER	10
Portfolio Optimization	Solve different formulations of the portfolio optimization problem.		
Multi-Car Paint Shop Optimization	Solve the multi-car paint shop optimization problem using the		
N Queens	Demonstrates how to formulate the n-queens problem as a QUBO, which we		

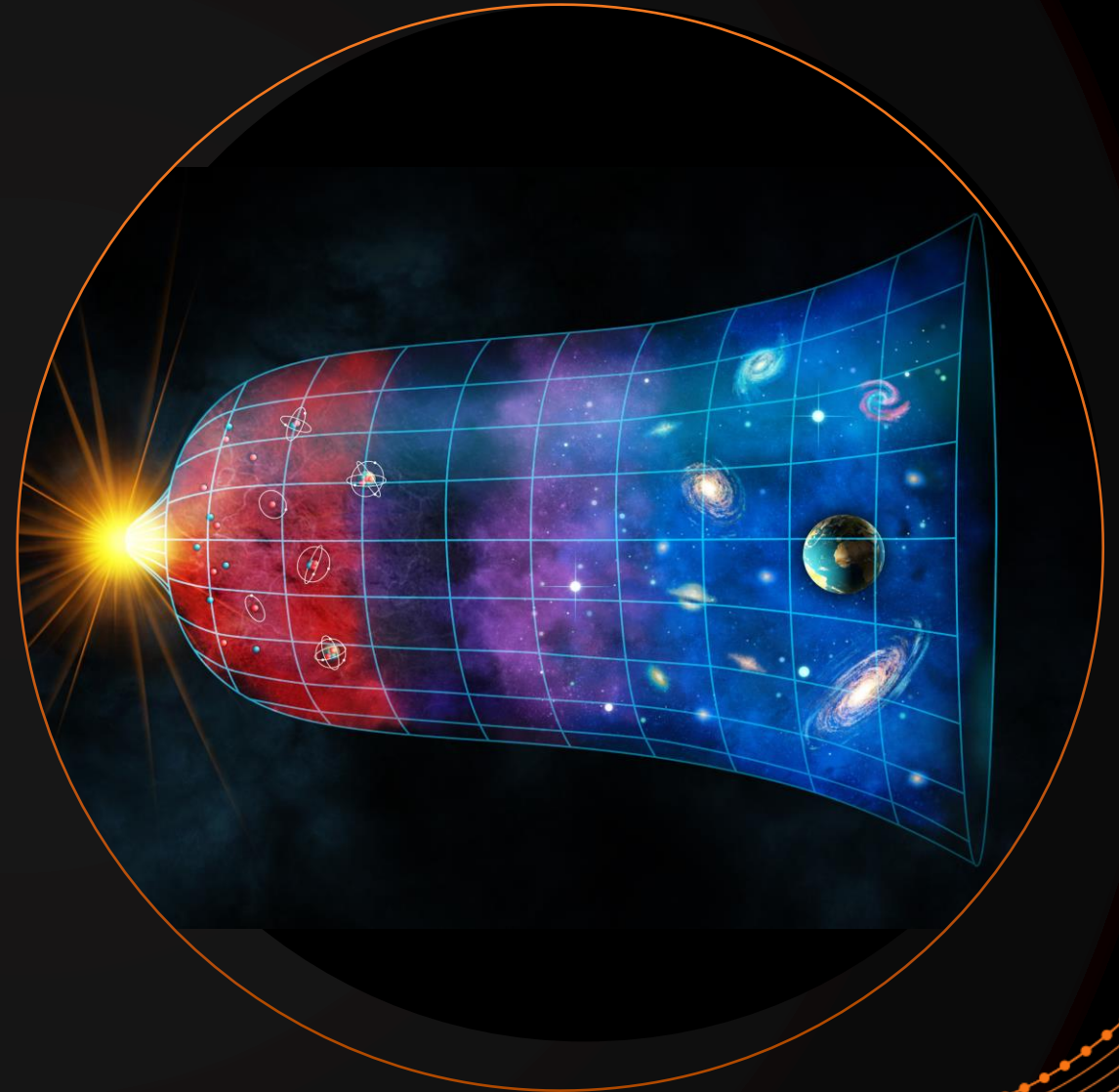


# Business Value Meets The Frontier of Advancing Science



# How Quickly Can Information Be Processed?

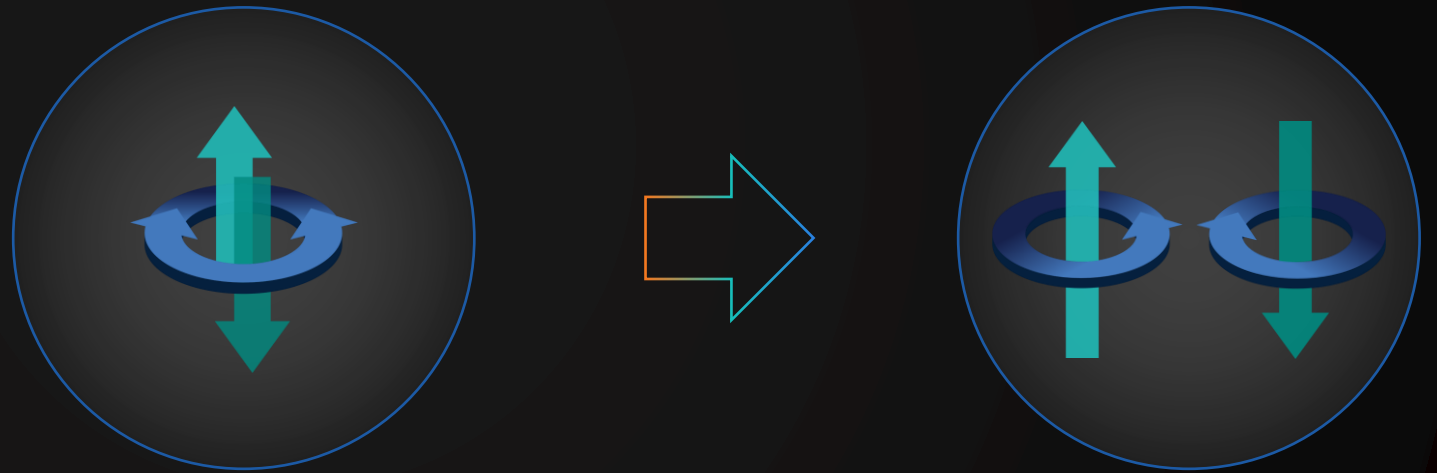
Tom Kibble determined the rates of domain structure formation in the early Universe



# Emergence of Structure in Quantum Computing



Wojciech Zurek related those rates to domain formation in quantum matter like superfluids



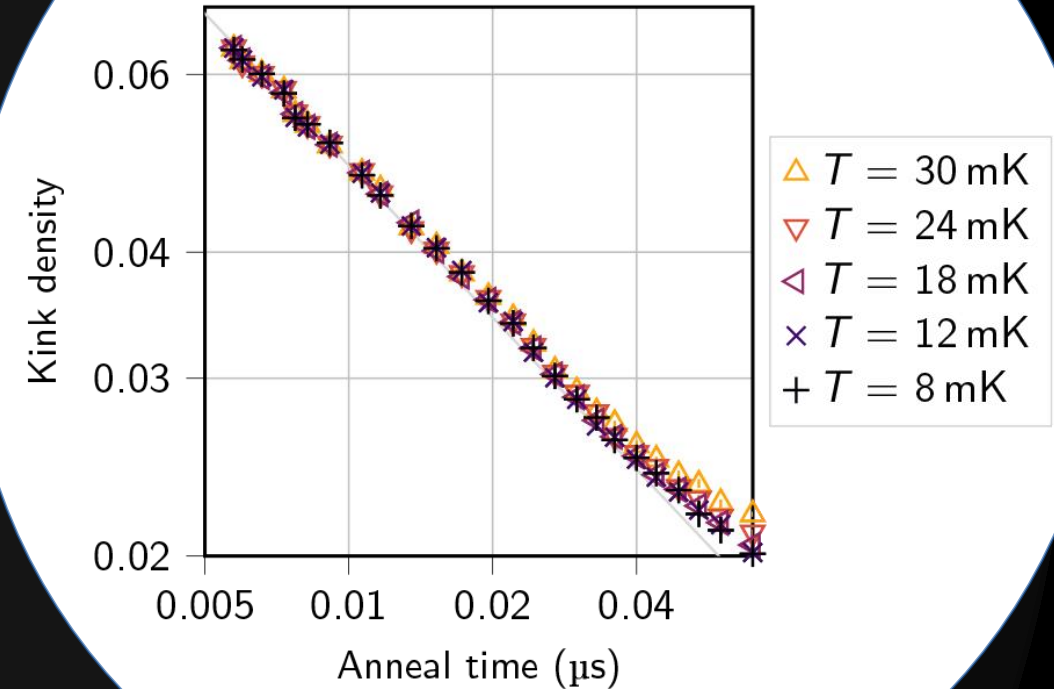


# Quantum And The Universe

The early Universe and quantum computing share common foundations

Coherent quantum annealing now observed in commercial quantum processors

Further disruptive accelerations are ahead



# Join The Masterclass On Friday



📅 Friday Nov 12 ⌚ 09:00 – 16:00

## Quantum Computing for Everyone

REGISTER



Victoria Goliber

*Senior quantum computing technical analyst*



Join Victoria to demystify the art of quantum computing in this hands-on programming workshop. By approaching quantum annealing through the lens of practical applications, you will leave this masterclass with an understanding of the basic building blocks required to solve real-world optimization problems on D-Wave's Leap™ quantum cloud service.

Together we will go through everything needed to create and run a python program using D-Wave's Ocean™ SDK, and will run these programs live on D-Wave's quantum computers and hybrid solvers.



## Next Steps to Learn More or Get Started Today

**D-Wave Applications:** Check out customer use cases and real-world applications.

➤ <https://www.dwavesys.com/applications>

**D-Wave Launch Program:** Learn about our multi-phased approach to quantum computing adoption.

➤ <https://www.dwavesys.com/d-wave-launch>

**D-Wave Leap Free Sign-Up:** Sign up for D-Wave Leap today to explore and get started.

➤ <https://cloud.dwavesys.com/leap/signup>

**Sign up for Access to Exclusive Content:** Sign up to get access to the content from the Qubits conference (Oct 5-7).

➤ <https://tinyurl.com/DWQubits>

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