goto; chicago

Fueling the Quantum Application Era with the Cloud

Murray Thom

follow us @gotochgo

Practical
Quantum Computing

Community

Building

Learning

Access

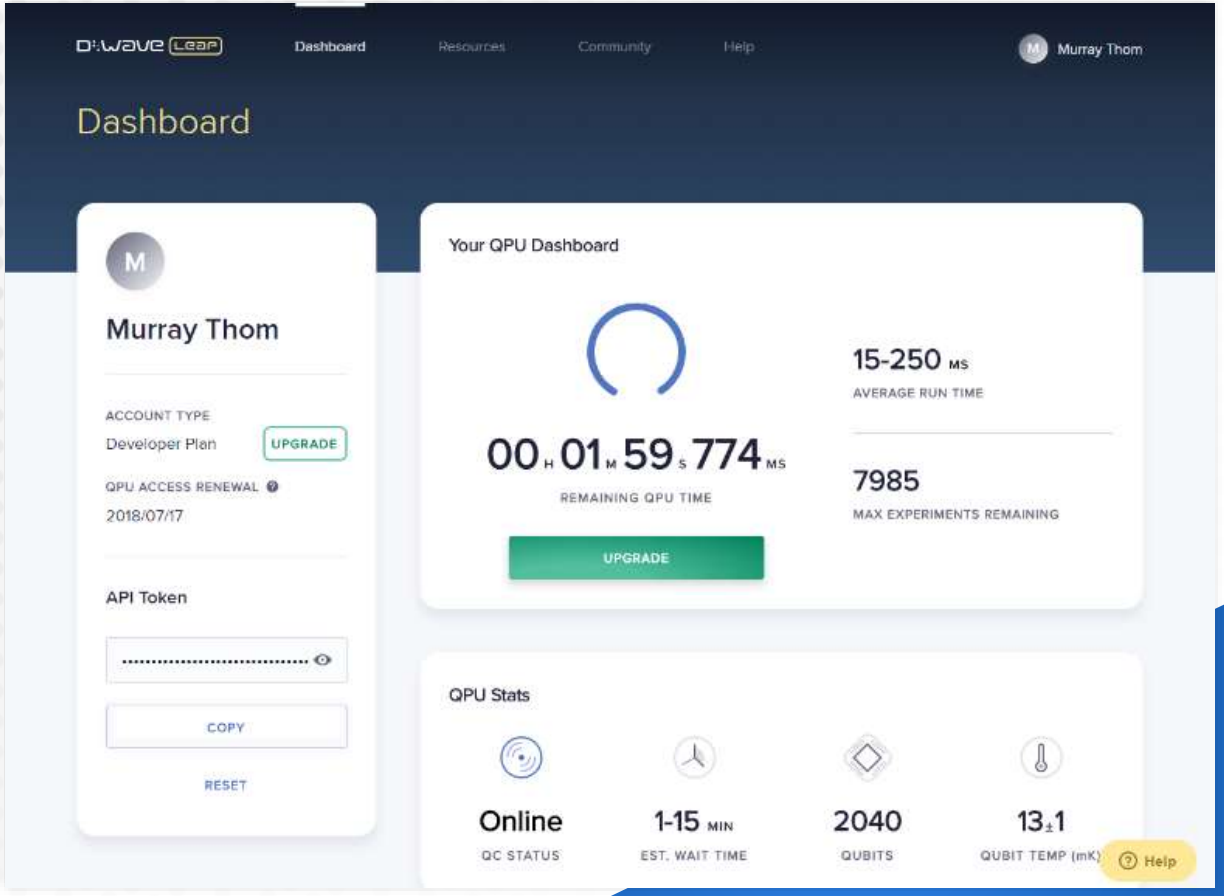
Copyright © D-Wave Systems Inc.

D:wave

D-Wave Leap™

The *Only* Real-Time Cloud Access & Quantum Application Environment

Enabling a New Developer Community



- Free Real-Time Cloud Access
- Integrated Open Source SDK
- Demos and Reference Code
- Community Support
- Online Training Resources

Copyright © D-Wave Systems Inc.

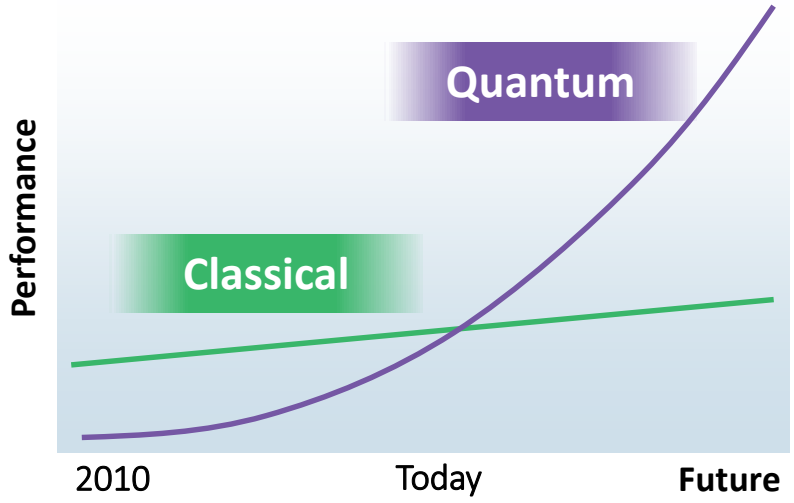
Why Quantum Computing?

Meeting the challenge of complex problems

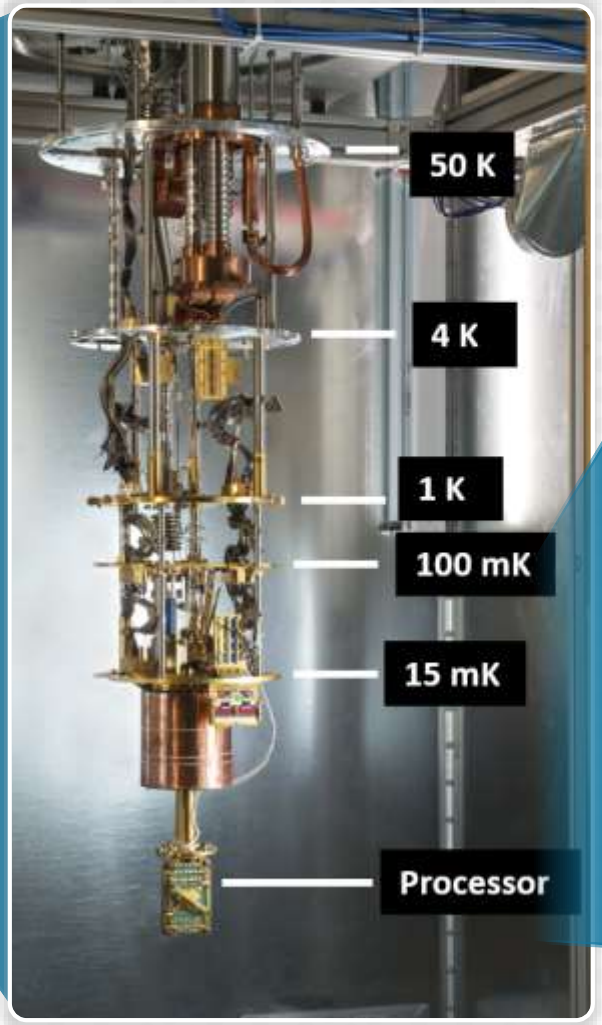
Performance beyond the reach of Moore's Law

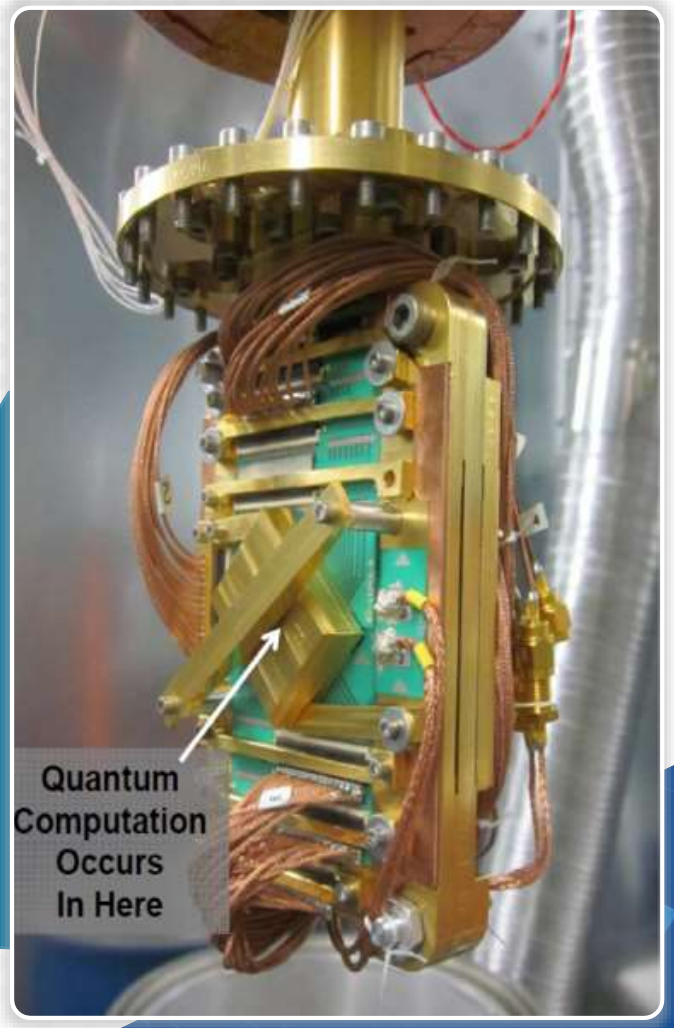
Transformative reduction in power consumption

Quantum computing offers a radical new solution

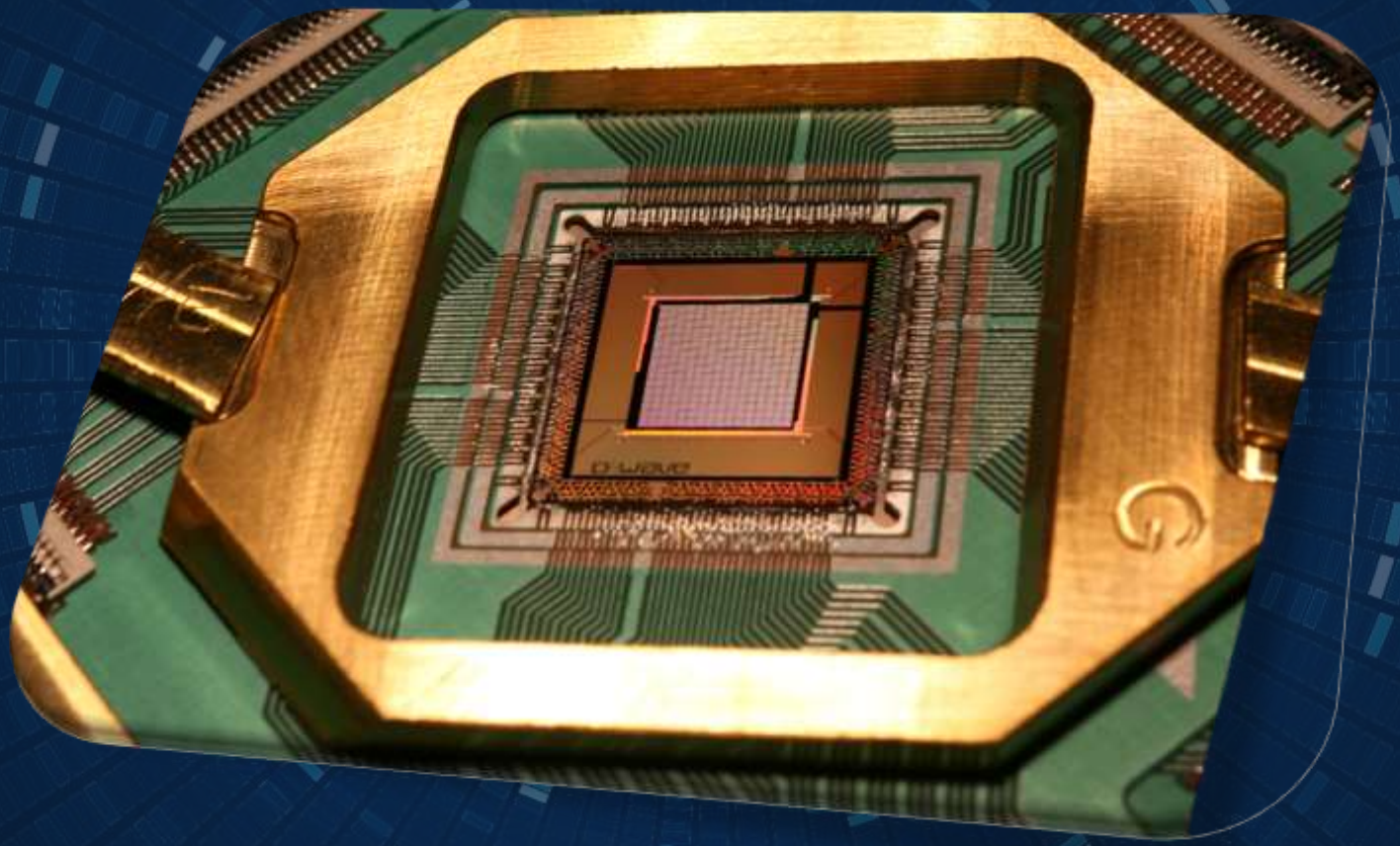


What Is A Quantum Computer?





Quantum Processing Unit (QPU)



Searching Vast Solution Landscapes

Problem: find the lowest point

Classical solution: Run very fast, to each point

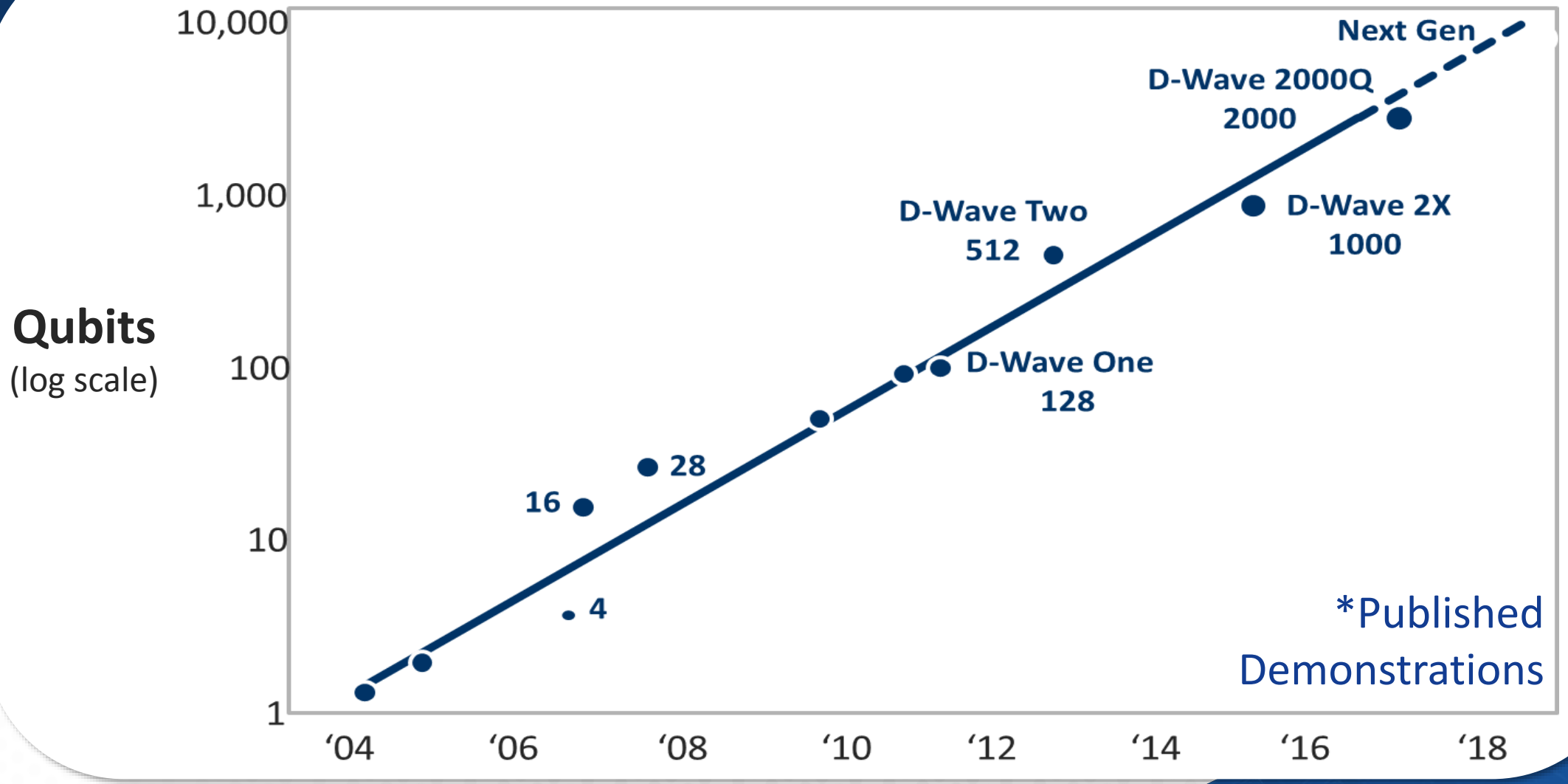
Quantum annealing solution: Visit many valleys at once, tunneling through the mountains

Quantum Machine Language

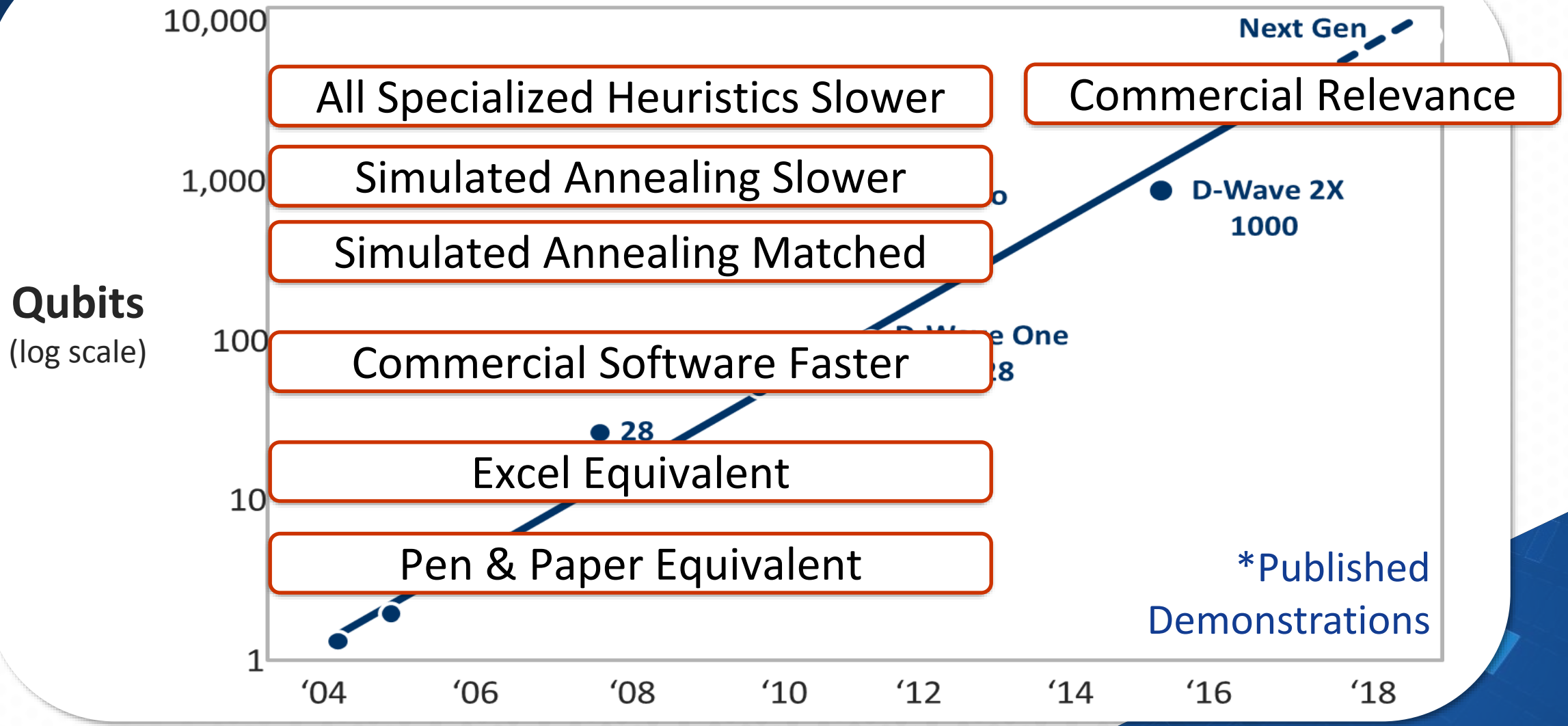
QUBIT	q_i	**Quantum bit** which participates in annealing cycle and settles into one of two possible final states: $\{0,1\}$
COUPLER	$q_i q_j$	Physical device that allows one **qubit to influence another qubit**
WEIGHT	a_i	Real-valued **constant associated with each qubit**, which influences the qubit's tendency to collapse into its two possible final states; controlled by the programmer
STRENGTH	b_{ij}	Real-valued **constant associated with each coupler**, which controls the influence exerted by one qubit on another; controlled by the programmer
OBJECTIVE	Obj	Real-valued **function which is minimized** during the annealing cycle

$$Obj(a_i, b_{ij}; q_i) = \sum_i a_i q_i + \sum_{ij} b_{ij} q_i q_j$$

Timeliness


Qubits
(log scale)
10,000
1,000
100
10
1
'04
'06
'08
'10
'12
'14
'16
'18
Next Gen
D-Wave 2000Q
2000
D-Wave 2X
1000
D-Wave Two
512
D-Wave One
128
28
16
4
*Published
Demonstrations

Timeliness


10,000
1,000
100
10
1
Qubits
(log scale)
Next Gen
Commercial Relevance
All Specialized Heuristics Slower
Simulated Annealing Slower
Simulated Annealing Matched
Commercial Software Faster
Excel Equivalent
Pen & Paper Equivalent
D-Wave 2X
1000
28
*Published
Demonstrations
'04
'06
'08
'10
'12
'14
'16
'18

Part Of Your Workflow (Beyond The Differences)

Equivalence at this layer
Entry to Application Workflow

Software

Algorithms

Sampling engine accessed as an algorithm

Co-processing resource used asynchronously

The effort is made to specify the problem

150+ EARLY APPLICATIONS

Materials Properties

- Atomic magnetometer
- Solid state materials simulation
- Quantum molecular dynamics
- Quantum chemistry computation

Optimization

- Radiotherapy
- Multi-period portfolios
- Satellite placement
- Traffic flow
- Internet ad placement

Machine Learning

- Finding Higgs Boson
- Image recognition
- Tree cover classifier
- DNA binding
- Individual cancer drugs

Cyber Security & Fault Detection

- Formation of Terrorist Networks
- Fault detection in circuits
- Facial recognition

Copyright © D-Wave Systems Inc.

D:wave

World Class **Customers**

Volkswagen

Copyright © D-Wave Systems Inc.

Early Applications

Copyright © D-Wave Systems Inc.

Breakthroughs: Materials Simulations

"This paper represents *a breakthrough in the simulation of physical systems which are otherwise essentially impossible*,"

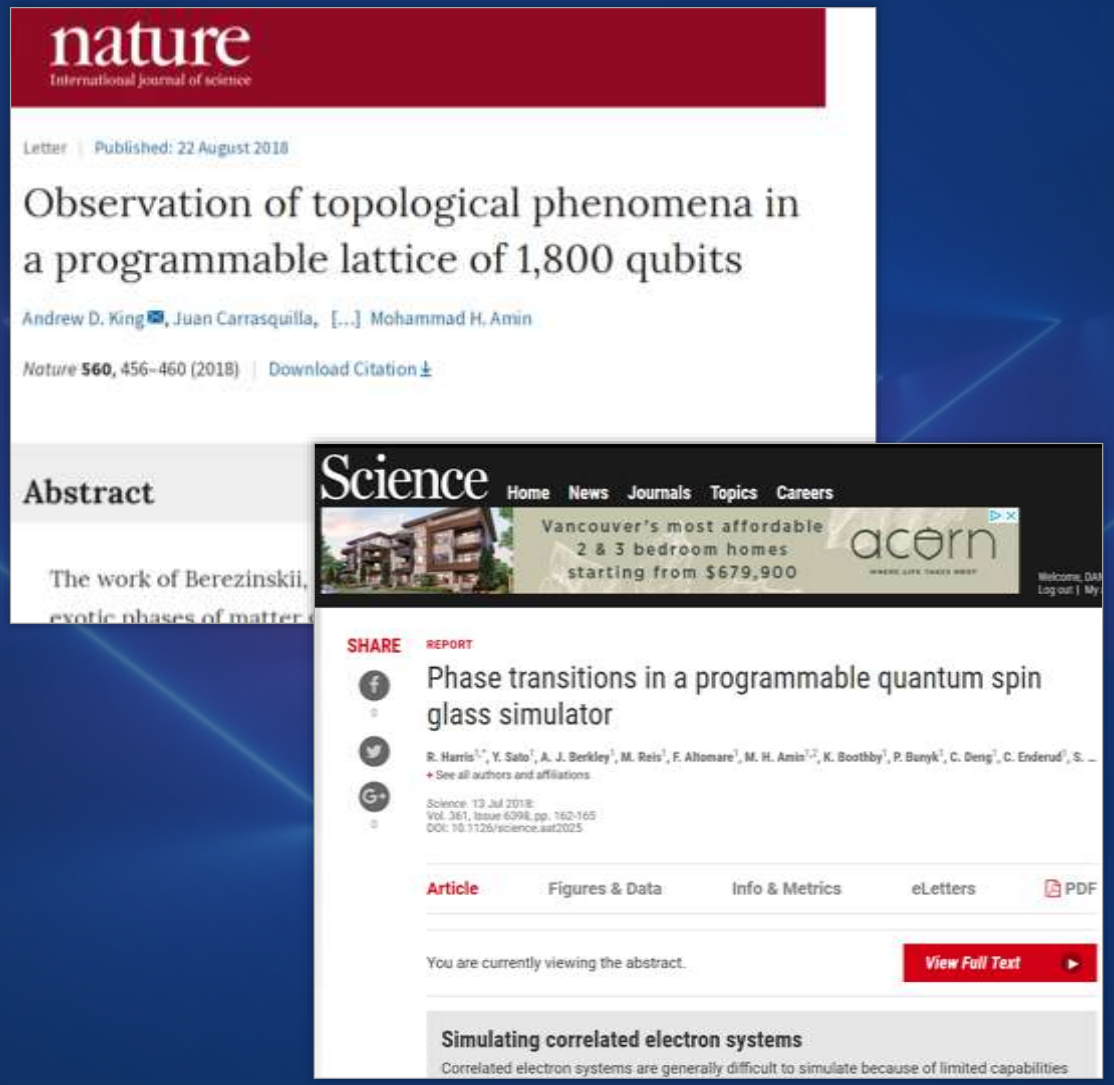
- Dr. J. Michael Kosterlitz,
2016 Nobel laureate in Physics

"…D-Wave scientists and engineers have accomplished a premiere goal of scientific computing…"

"While it's not a demonstration of the "quantum supremacy" sought by pundits of quantum computing, it is a more important accomplishment because the problem they've attacked is one of immediate significance to today's advanced technology sectors and it is the first truly useful application of a quantum computer."

- E.H. "Ned" Allen Ph.D.,
Chief Scientist and Corporate Senior Fellow at **Lockheed Martin**

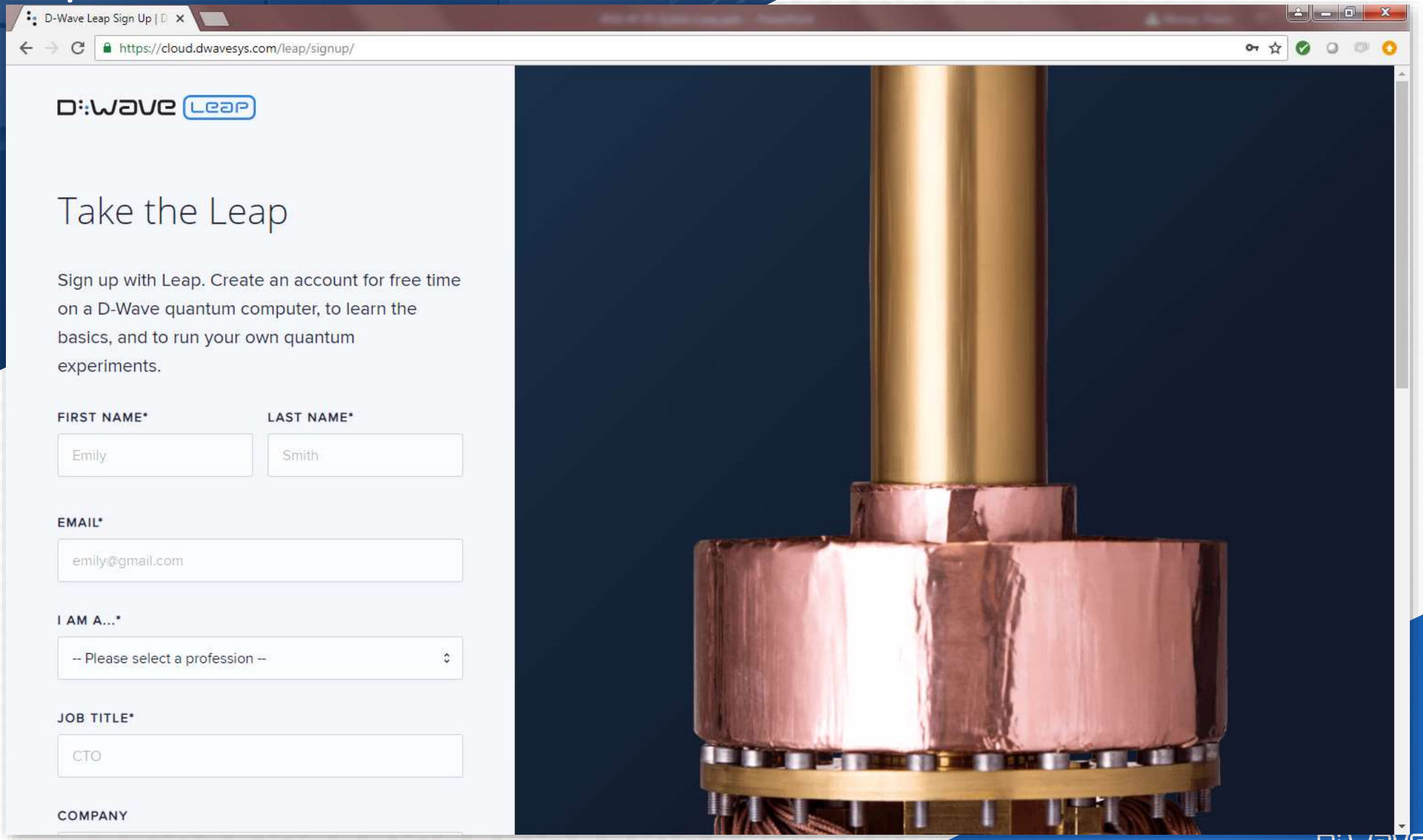
https://www.nature.com/articles/s41586-018-0410-x



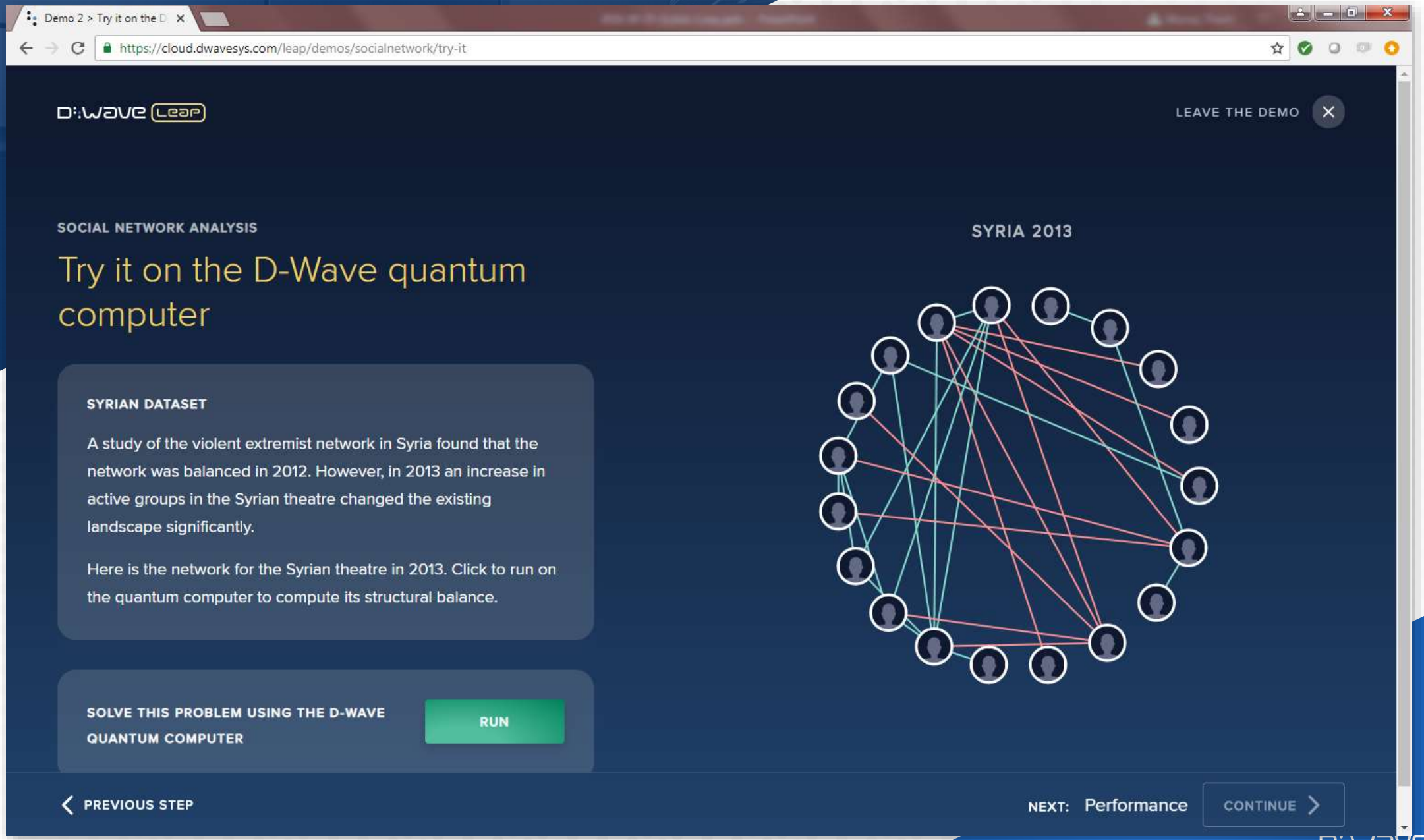
http://science.sciencemag.org/content/361/6398/162

Copyright © D-Wave Systems Inc.

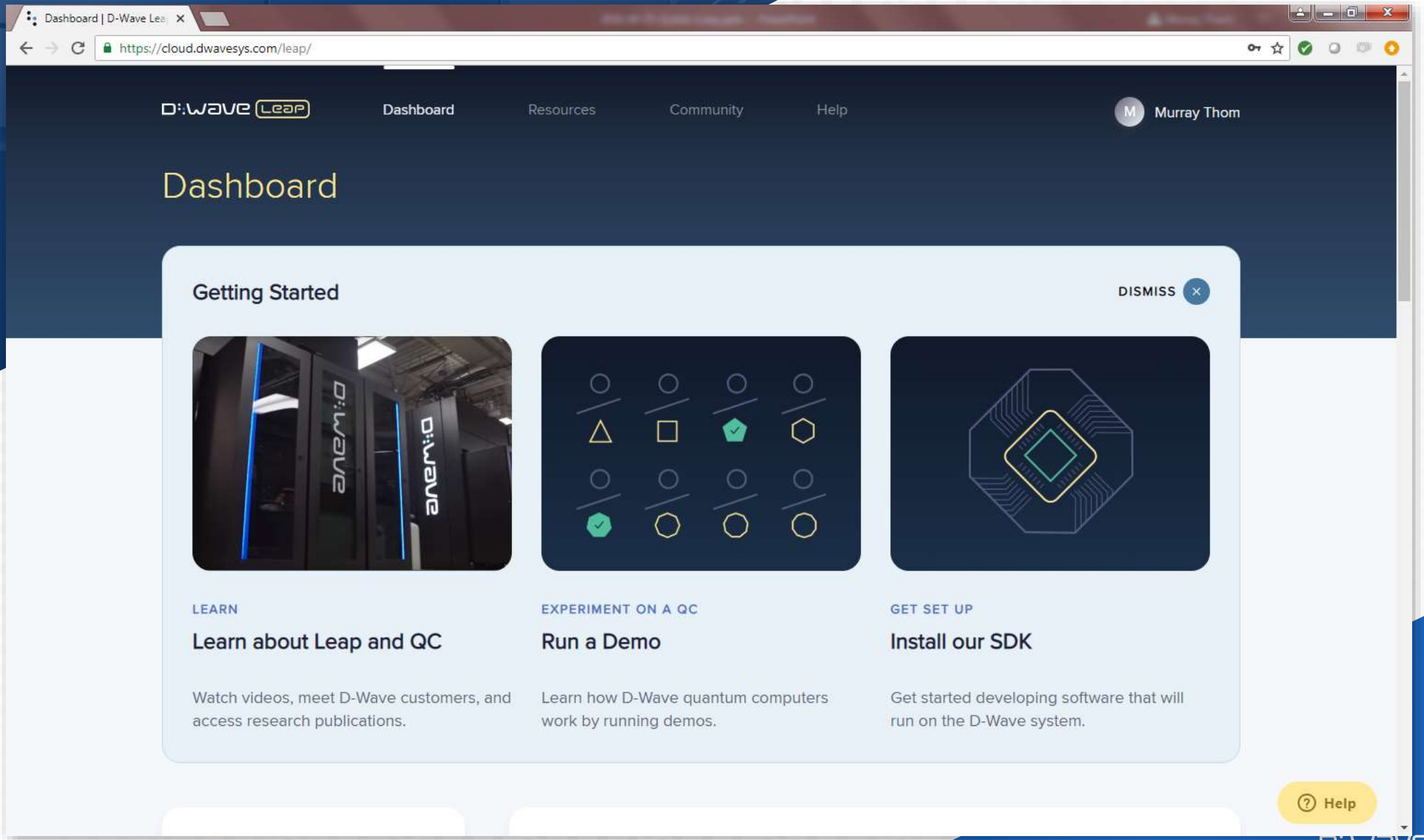
Take The Leap



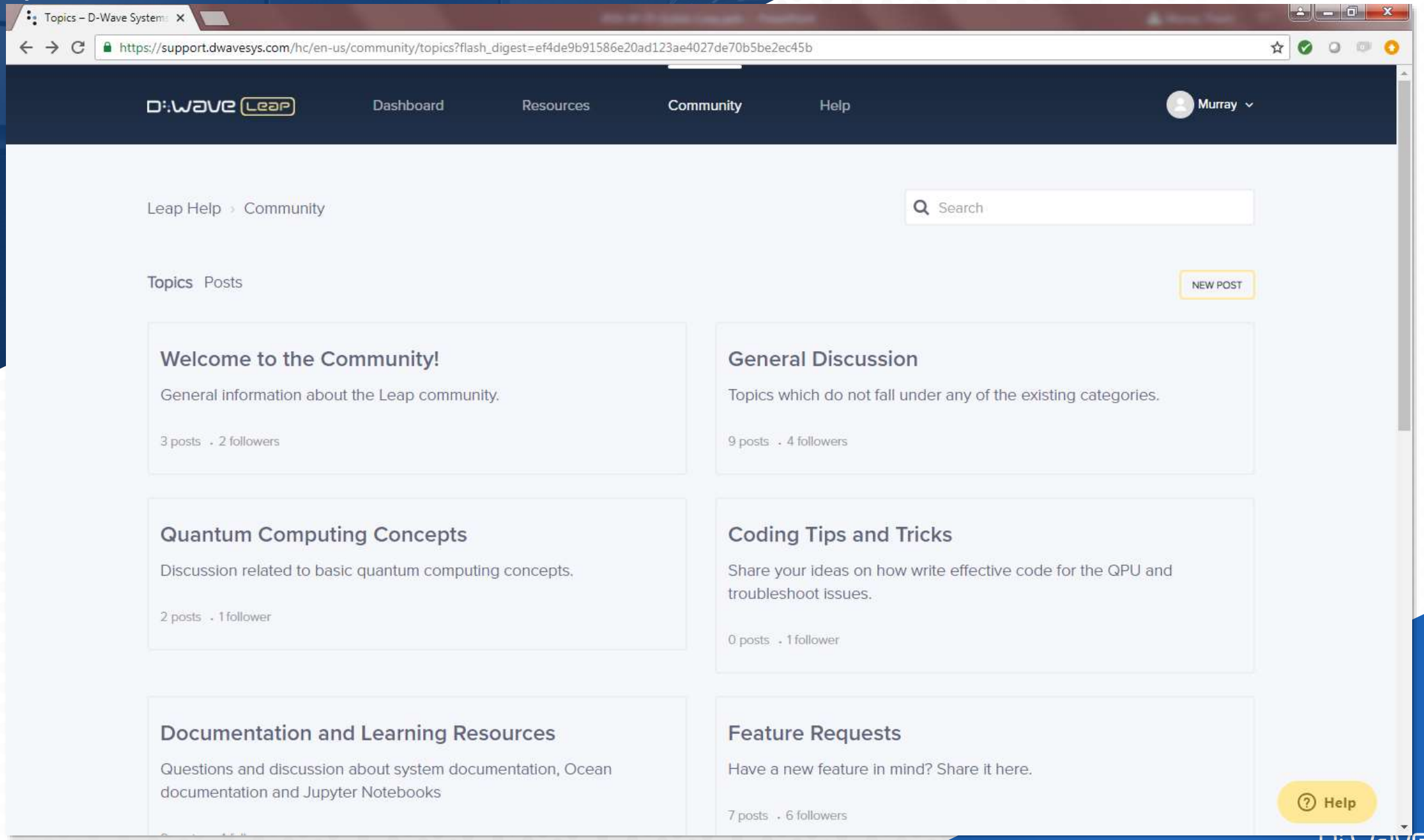
Illustrated Demos



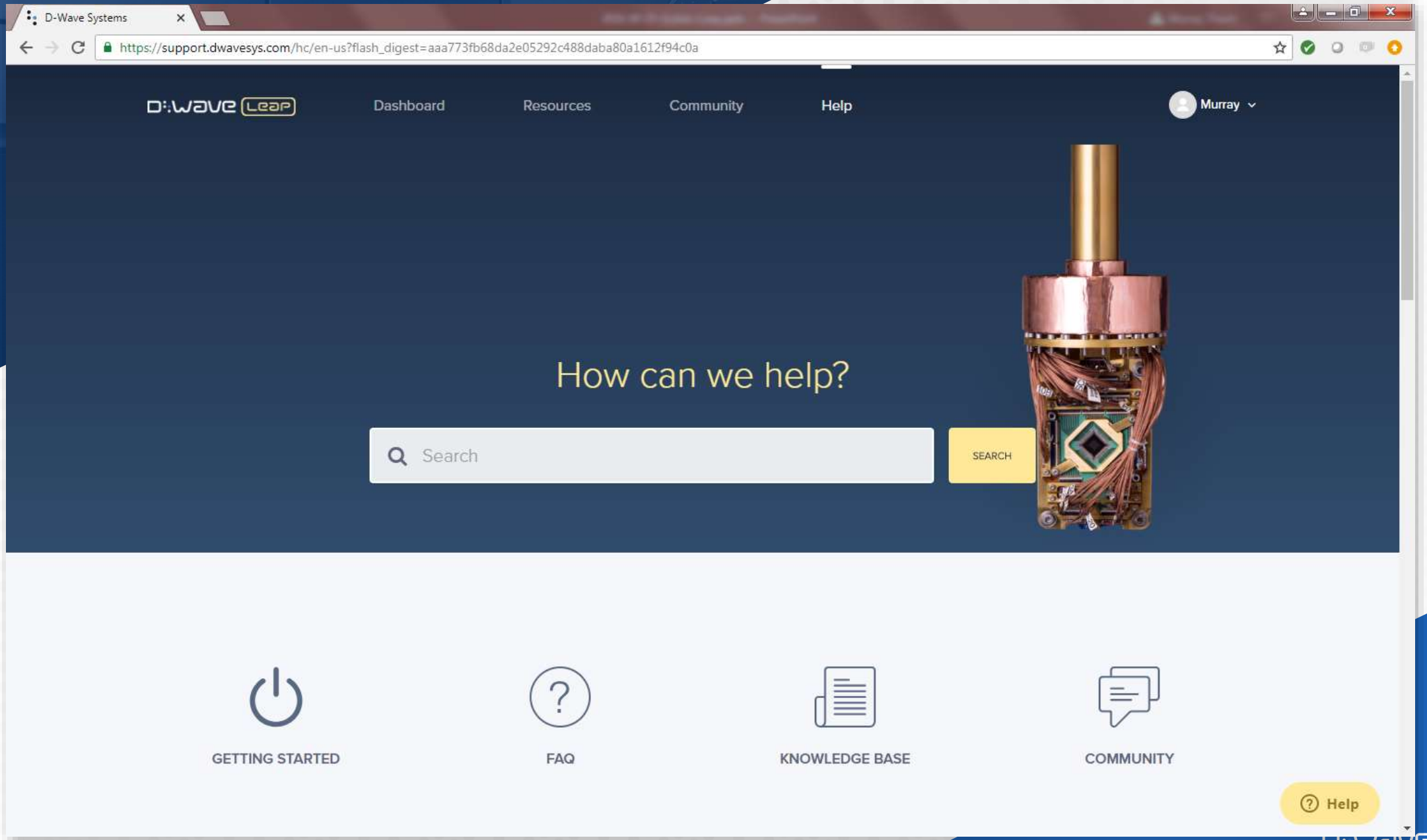
Leap Dashboard



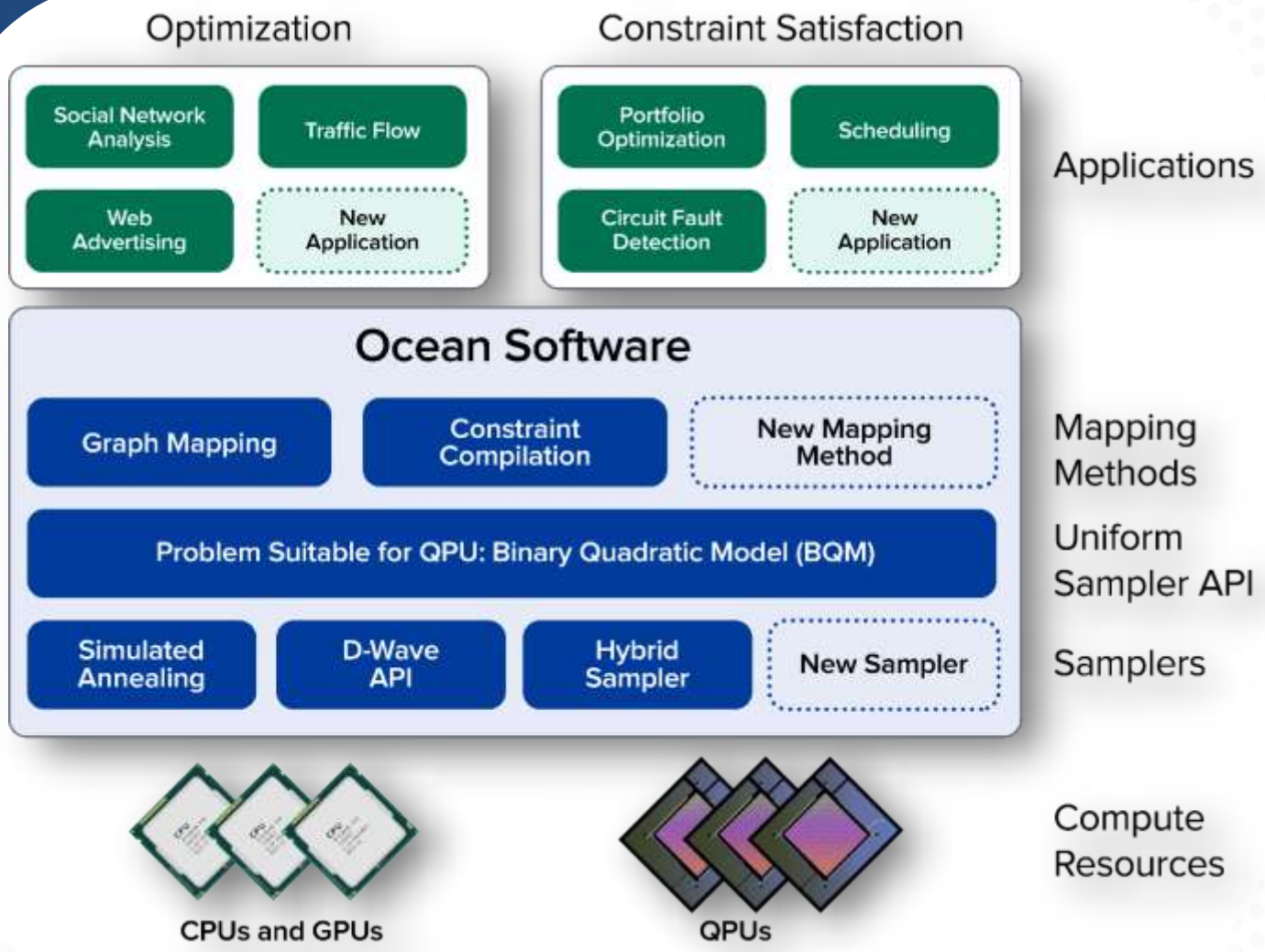
Community Forums



support.dwavesys.com



Ocean Software Stack



How to Install

Installing the Ocean Tool Suite:

pip install dwave-ocean-sdk

Leap:
cloud.dwavesys.com/leap

GitHub:
github.com/dwavesystems

Docs:
docs.ocean.dwavesys.com

github.com/dwavesystems/**demos**

Work In Progress

Providing some example starting points

- circuit-fault-diagnosis
- factoring
- structural-imbalance
- **maze solving**
- **qboost binary classification**
- **job-shop-scheduling**

D-Wave Hybrid™ Workflow Platform

Framework for Building and Running Quantum-Classical Hybrid Applications

Hybrid Workflow Control

Modular Approach

Large Problem Decomposition

Familiar Coding Environment

```
subproblem_size = min(len(bqm), max_subproblem_size)

iteration = RacingBranches(
    InterruptableTabuSampler(),
    IdentityDecomposer()
        | SimulatedAnnealingSubproblemSampler(num_reads=
        | SplatComposer(),
    EnergyImpactDecomposer(max_size=subproblem_size, mi
        | QPUSubproblemAutoEmbeddingSampler(num_reads=q
        | SplatComposer(),
) | ArgMin()
self.runnable = Loop(iteration, max_iter=max_iter, conv
```

Copyright © D-Wave Systems Inc.

Practical
Quantum Computing

Community

Building

Learning

Access

Copyright © D-Wave Systems Inc.

D:wave

goto; chicago

Please

Remember to rate this session

Thank you!

follow us @gotochgo