

# Fueling the Quantum Application Era with the Cloud

*Murray Thom*

# Practical Quantum Computing

Community

Building

Learning

Access

# D-Wave Leap™

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

## Enabling a New Developer Community

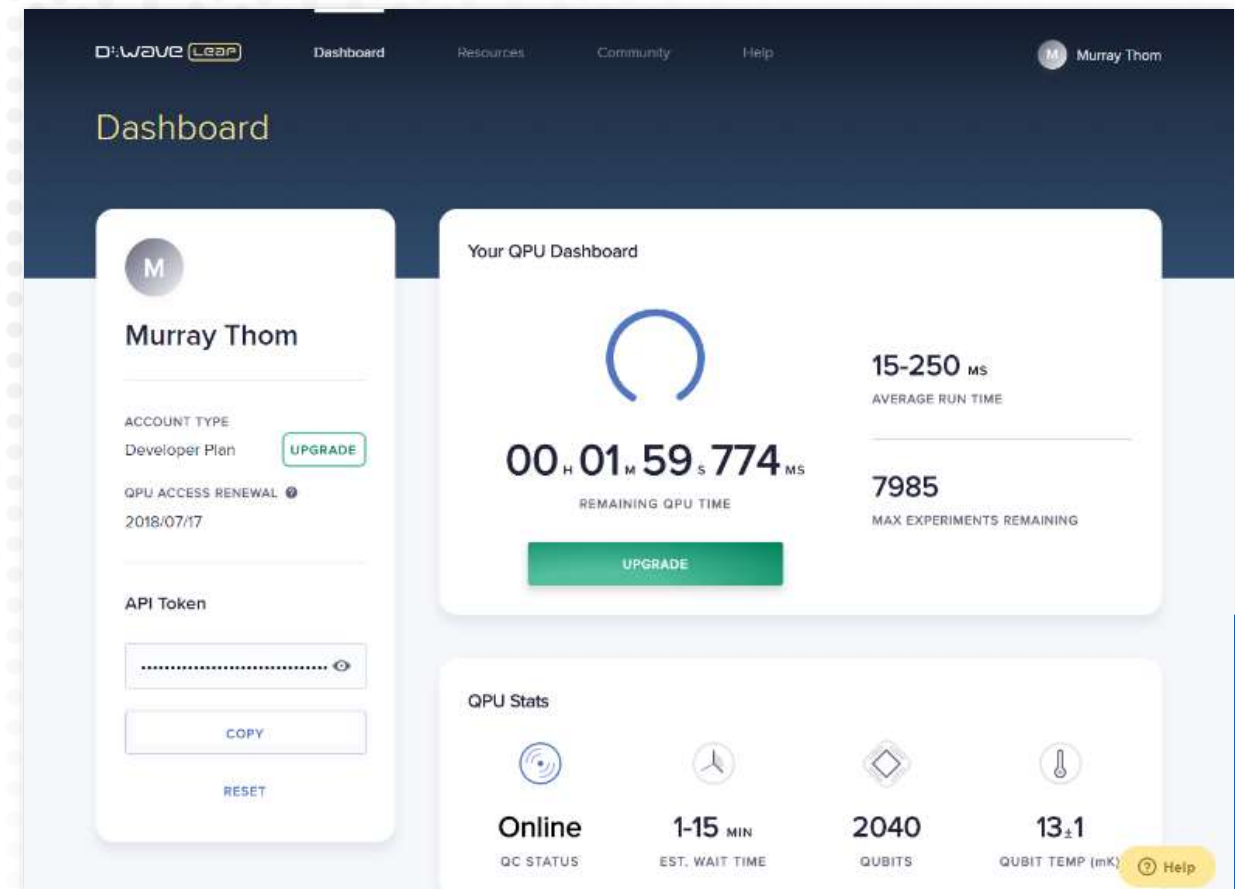
Free Real-Time Cloud Access

Integrated Open Source SDK

Demos and Reference Code

Community Support

Online Training Resources





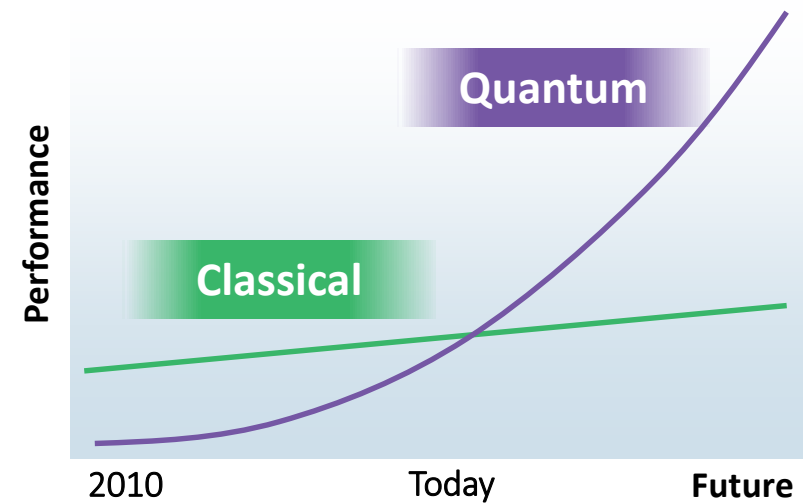
# Why Quantum Computing?

Meeting the challenge of complex problems

Performance beyond the reach of Moore's Law

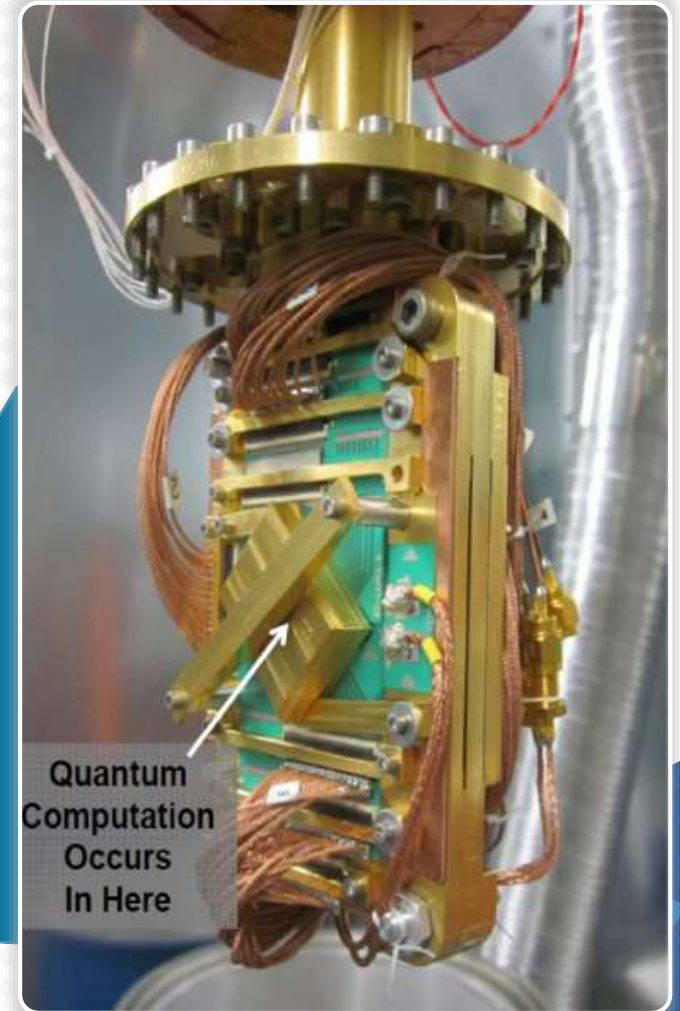
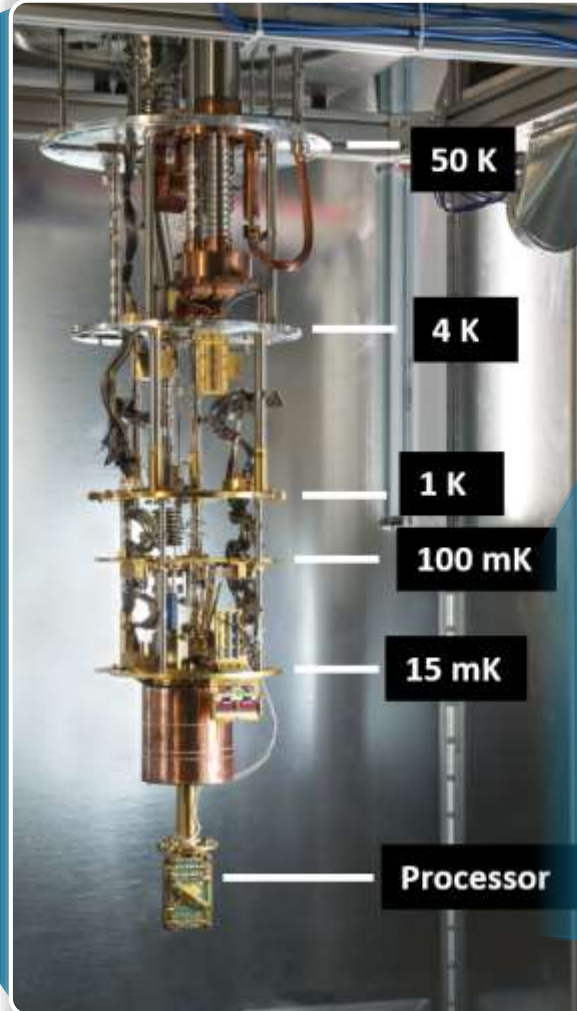
Transformative reduction in power consumption

*Quantum* computing offers a radical new solution



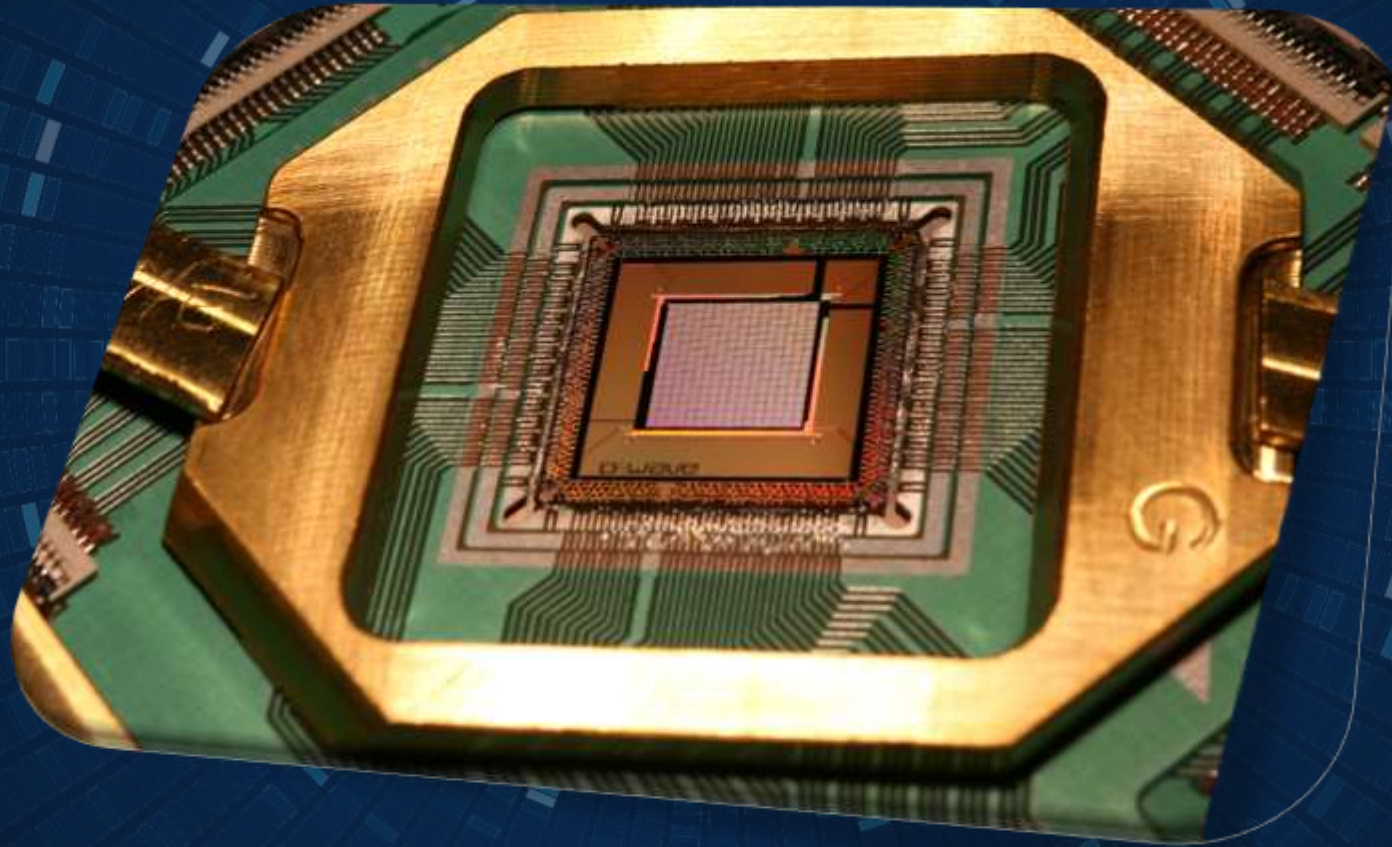


# What Is A Quantum Computer?





# 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



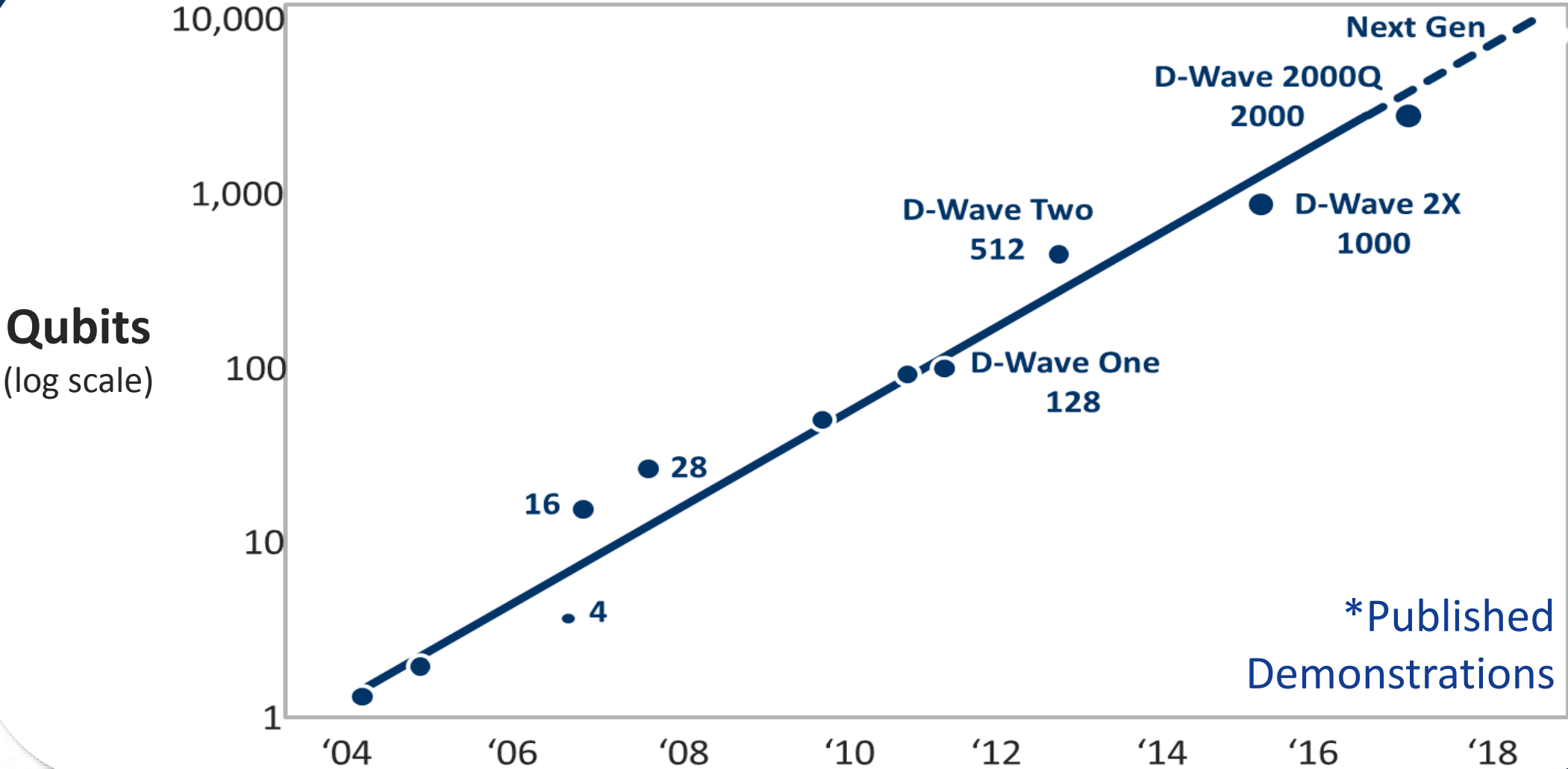


# Quantum Machine Language

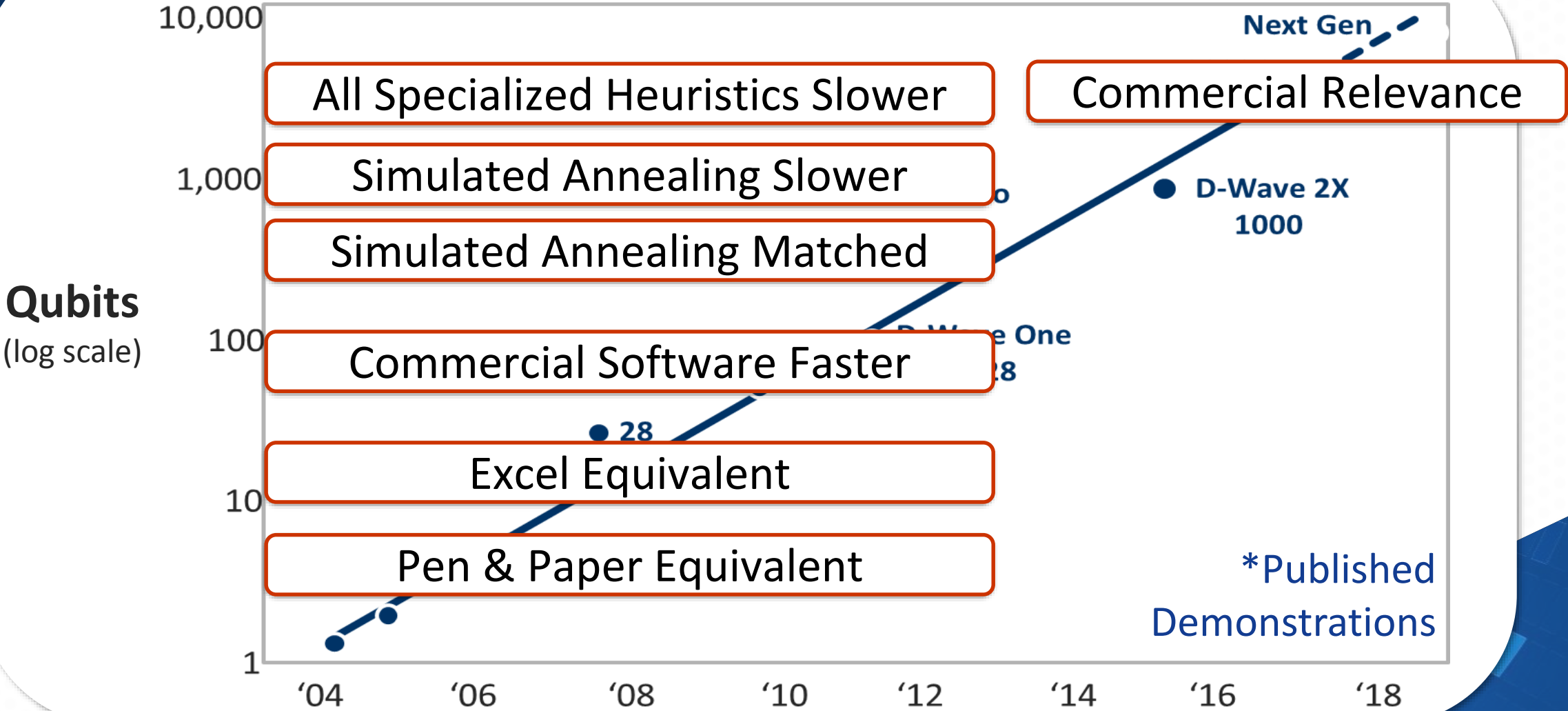
QUBIT	$q_i$	<b>Quantum bit</b> which participates in annealing cycle and settles into one of two possible final states: $\{0,1\}$
COUPLER	$q_i q_j$	Physical device that allows one <b>qubit to influence another qubit</b>
WEIGHT	$a_i$	Real-valued <b>constant associated with each qubit</b> , which influences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



# Timeliness





# 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

# Materials Properties

Atomic magnetometer

Solid state materials simulation

Quantum molecular dynamics

Quantum chemistry computation

150+  
EARLY  
APPLICATIONS

Finding Higgs Boson

Image recognition

Tree cover classifier

DNA binding

Individual cancer drugs

# Machine Learning

# Optimization

Radiotherapy

Multi-period portfolios

Satellite placement

Traffic flow

Internet ad placement

Formation of Terrorist Networks

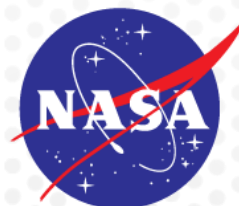
Fault detection in circuits

Facial recognition

# Cyber Security & Fault Detection



# World Class Customers



Volkswagen





## Early Applications



## Volkswagen Boosts Battery Research Using Quantum Computing

Technology companies Google and D-Wave are providing VW experts access to their systems to build battery technology for EVs.

BY GEORGE KURUVILLA JUNE 12, 2018



## Volkswagen Uses Quantum Computing to Fight Beijing Traffic

Volkswagen teamed with D-Wave Systems to run a traffic-flow algorithm on a quantum computer, with encouraging results.

BY STEPHEN EDELSTEIN MARCH 30, 2017



# Breakthroughs: Materials Simulations

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

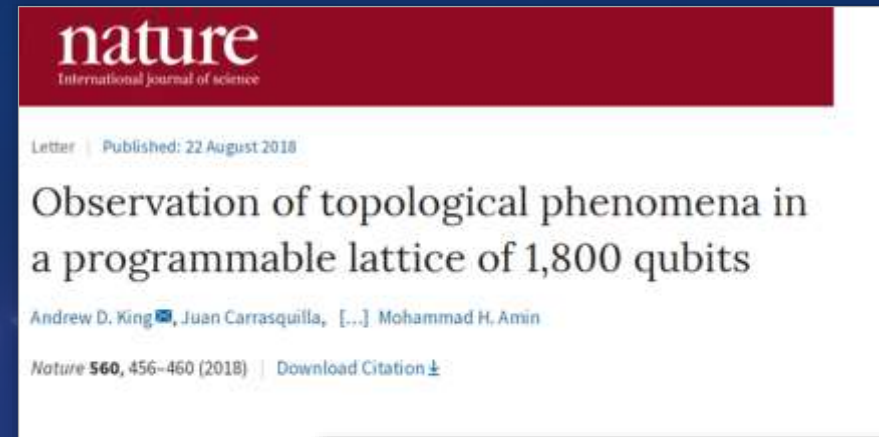
- Dr. J. Michael Kosterlitz,  
**2016 Nobel laureate in Physics**

“...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**

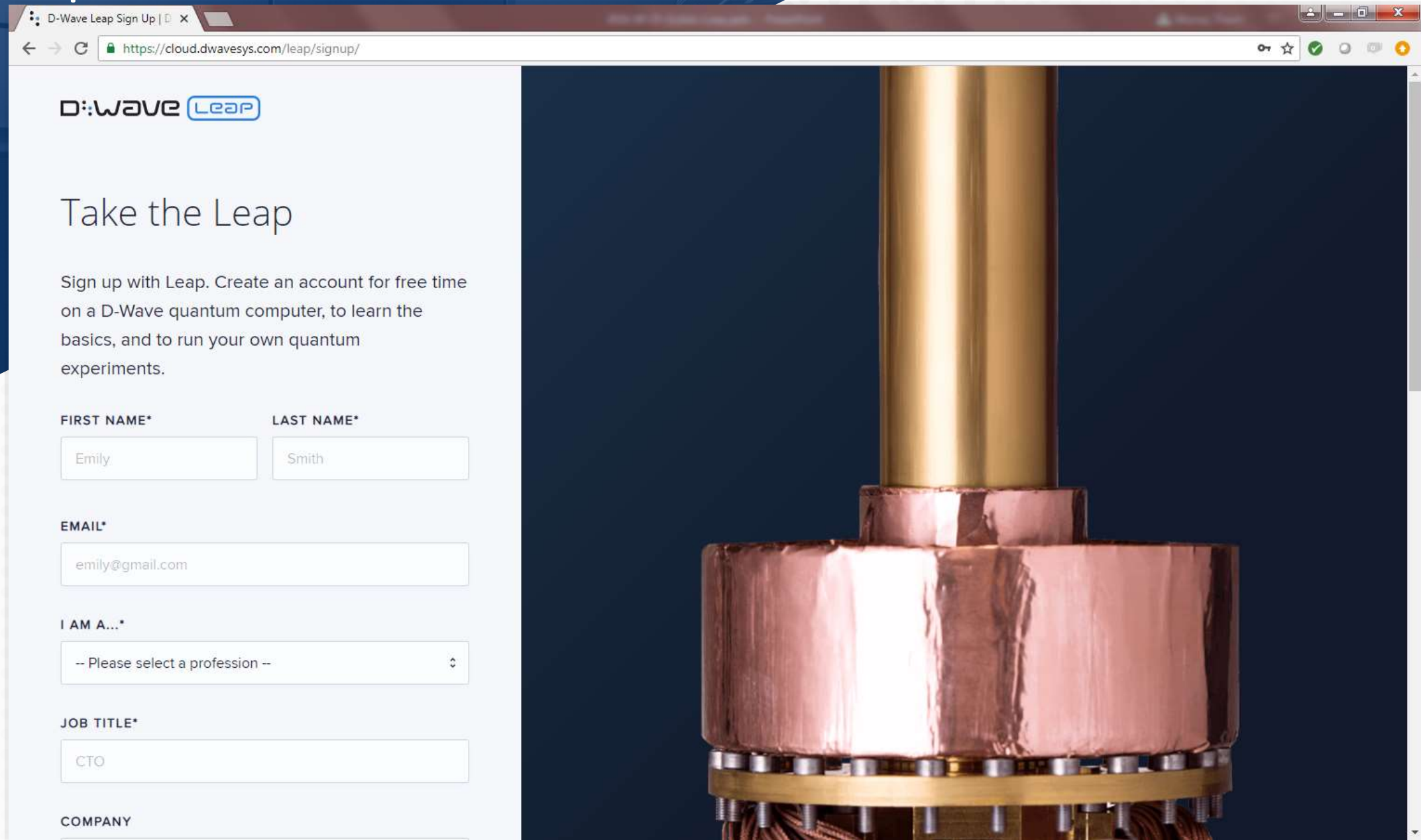
<https://www.nature.com/articles/s41586-018-0410-x>



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



# Take The Leap

A screenshot of a web browser displaying the D-Wave Leap Sign Up page. The browser's address bar shows the URL 'https://cloud.dwavesys.com/leap/signup/'. The page features the D-Wave Leap logo at the top left. Below the logo, the heading 'Take the Leap' is displayed. A paragraph of text explains the purpose of the sign-up: 'Sign up with Leap. Create an account for free time on a D-Wave quantum computer, to learn the basics, and to run your own quantum experiments.' The form contains several input fields: 'FIRST NAME\*' with the value 'Emily', 'LAST NAME\*' with the value 'Smith', 'EMAIL\*' with the value 'emily@gmail.com', 'I AM A...\*' with a dropdown menu showing '-- Please select a profession --', 'JOB TITLE\*' with the value 'CTO', and 'COMPANY' which is currently empty. On the right side of the page, there is a large image of a quantum processor component, showing a vertical copper rod and several horizontal copper rings. The background of the page is dark blue with a subtle pattern of white dots.

D-Wave Leap Sign Up | X

https://cloud.dwavesys.com/leap/signup/

**D-WAVE** LEAP

## Take the Leap

Sign up with Leap. Create an account for free time on a D-Wave quantum computer, to learn the basics, and to run your own quantum experiments.

**FIRST NAME\***  **LAST NAME\***

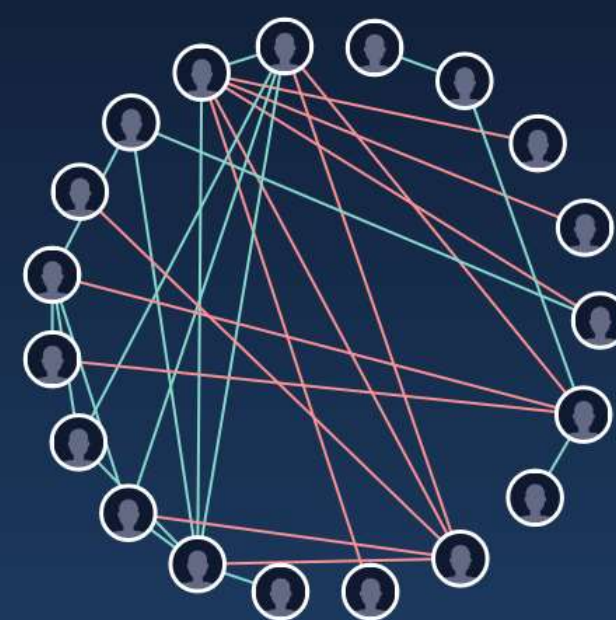
**EMAIL\***

**I AM A...\***

**JOB TITLE\***

**COMPANY**





# Leap Dashboard

Dashboard | D-Wave Leap X


https://cloud.dwavesys.com/leap/

D-WAVE LEAP Dashboard Resources Community Help M Murray Thom

## Dashboard

### Getting Started


DISMISS



**LEARN**

#### Learn about Leap and QC


Watch videos, meet D-Wave customers, and access research publications.



**EXPERIMENT ON A QC**

#### Run a Demo

Learn how D-Wave quantum computers work by running demos.



**GET SET UP**

#### Install our SDK

Get started developing software that will run on the D-Wave system.

? Help



# Community Forums

The screenshot shows a web browser window displaying the D-Wave Leap Community Forums. The browser's address bar shows the URL: [https://support.dwavesys.com/hc/en-us/community/topics?flash\\_digest=ef4de9b91586e20ad123ae4027de70b5be2ec45b](https://support.dwavesys.com/hc/en-us/community/topics?flash_digest=ef4de9b91586e20ad123ae4027de70b5be2ec45b). The page has a dark blue header with the D-Wave Leap logo and navigation links: Dashboard, Resources, Community, and Help. A user profile for 'Murray' is visible in the top right. Below the header, the page is titled 'Leap Help > Community' and includes a search bar. A 'NEW POST' button is located in the top right of the forum area. The forum is organized into a grid of topic cards. Each card has a title, a brief description, and statistics for posts and followers. The topics listed are: 'Welcome to the Community!', 'General Discussion', 'Quantum Computing Concepts', 'Coding Tips and Tricks', 'Documentation and Learning Resources', and 'Feature Requests'. A yellow 'Help' button is located in the bottom right corner of the forum area.

Topics – D-Wave Systems

[https://support.dwavesys.com/hc/en-us/community/topics?flash\\_digest=ef4de9b91586e20ad123ae4027de70b5be2ec45b](https://support.dwavesys.com/hc/en-us/community/topics?flash_digest=ef4de9b91586e20ad123ae4027de70b5be2ec45b)

D-WAVE LEAP Dashboard Resources Community Help Murray

Leap Help > Community

Search

Topics Posts NEW POST

**Welcome to the Community!**  
General information about the Leap community.  
3 posts · 2 followers

**General Discussion**  
Topics which do not fall under any of the existing categories.  
9 posts · 4 followers

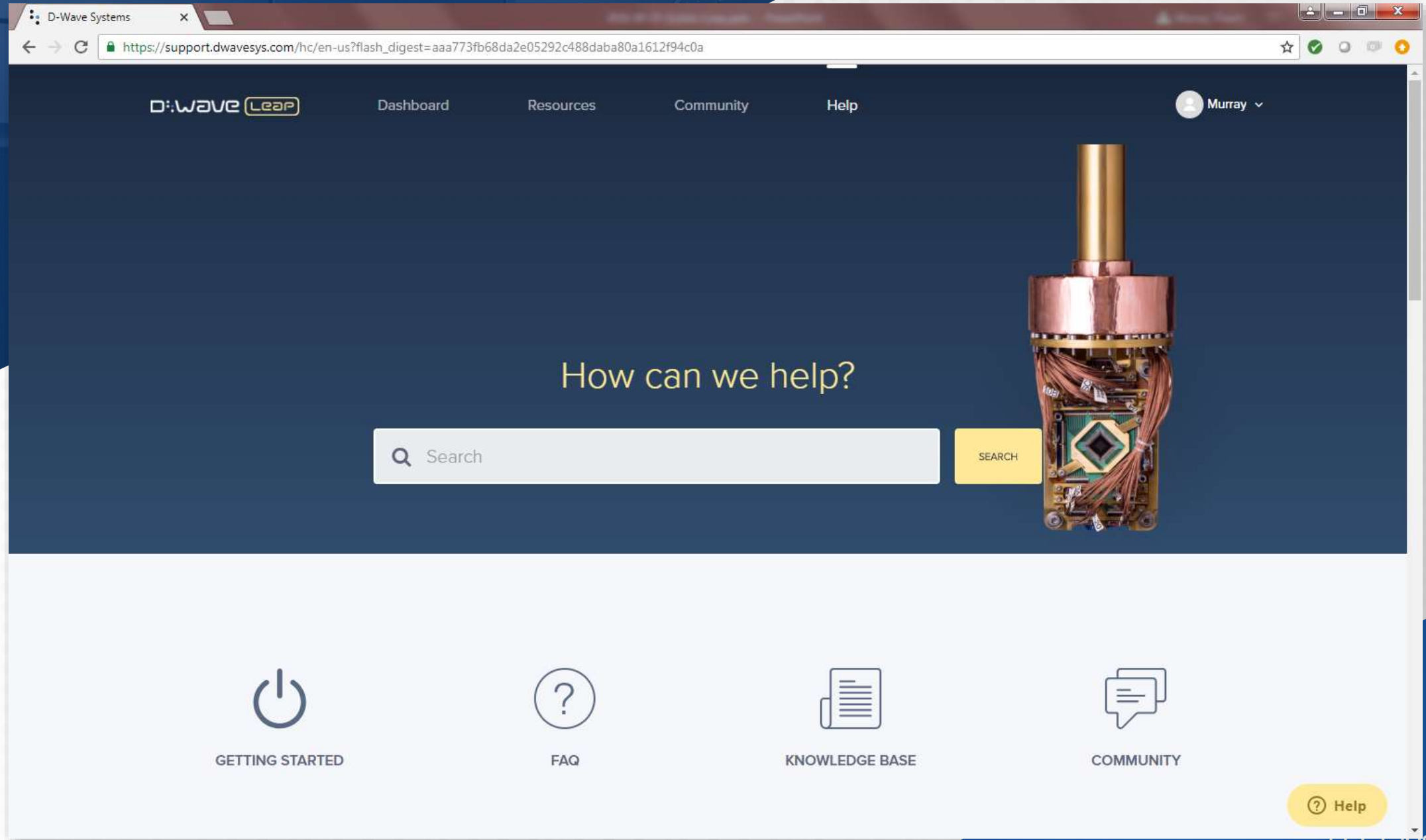
**Quantum Computing Concepts**  
Discussion related to basic quantum computing concepts.  
2 posts · 1 follower

**Coding Tips and Tricks**  
Share your ideas on how write effective code for the QPU and troubleshoot issues.  
0 posts · 1 follower

**Documentation and Learning Resources**  
Questions and discussion about system documentation, Ocean documentation and Jupyter Notebooks

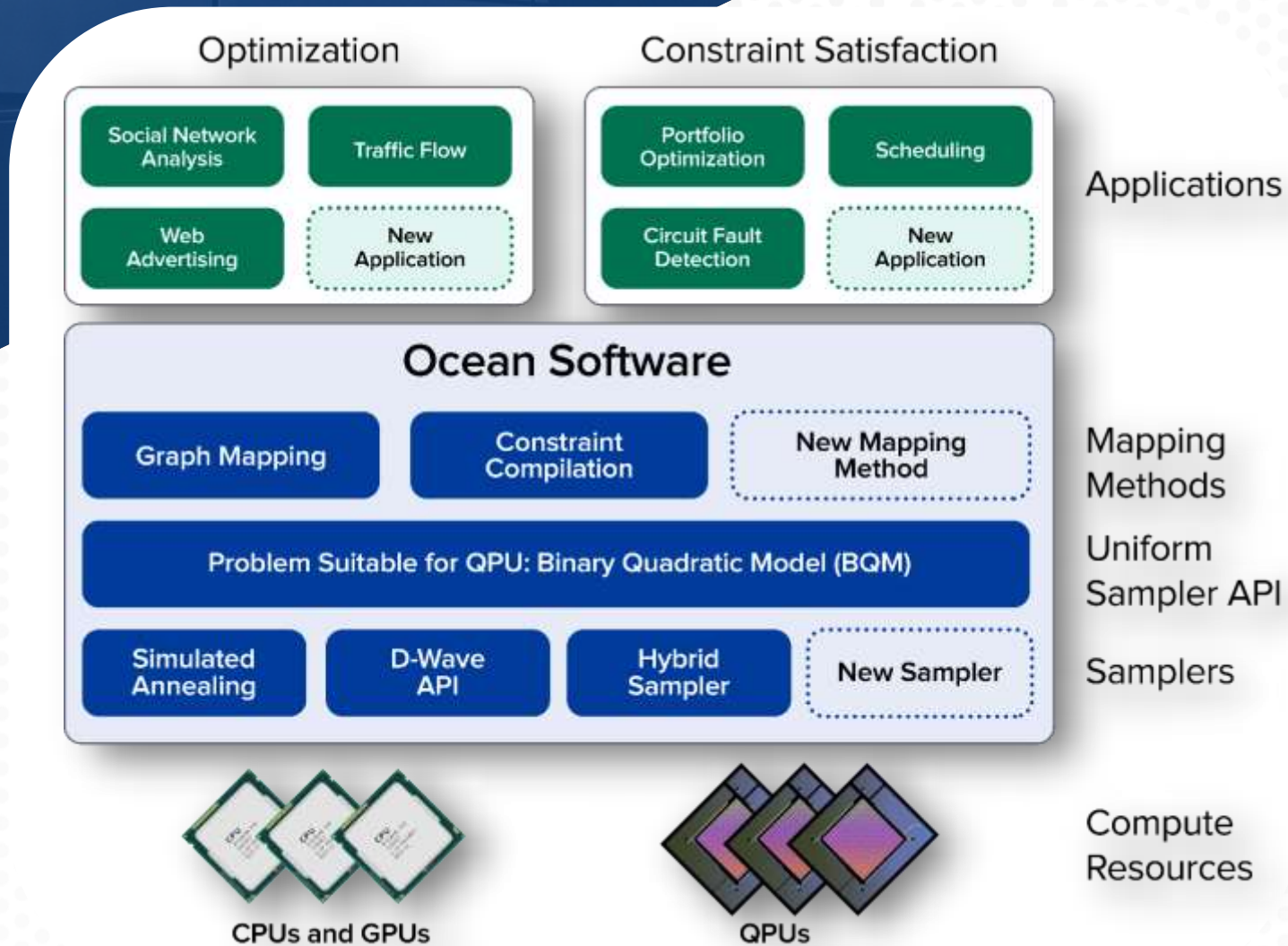
**Feature Requests**  
Have a new feature in mind? Share it here.  
7 posts · 6 followers

Help





# Ocean Software Stack



# How to Install

*Installing the Ocean Tool Suite:*

**pip install dwave-ocean-sdk**

**Leap:**  
**[cloud.dwavesys.com/leap](https://cloud.dwavesys.com/leap)**

**GitHub:**  
**[github.com/dwavesystems](https://github.com/dwavesystems)**

**Docs:**  
**[docs.ocean.dwavesys.com](https://docs.ocean.dwavesys.com)**



[github.com/dwavesystems/demos](https://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=1000),
    SplatComposer(),
    EnergyImpactDecomposer(max_size=subproblem_size, min_size=1),
    QPUSubproblemAutoEmbeddingSampler(num_reads=1000),
    SplatComposer(),
) | ArgMin()

self.runnable = Loop(iteration, max_iter=max_iter, convergence=1e-6)
```



# Practical Quantum Computing

Community

Building

Learning

Access



*Please*

**Remember to  
rate this session**

*Thank you!*

