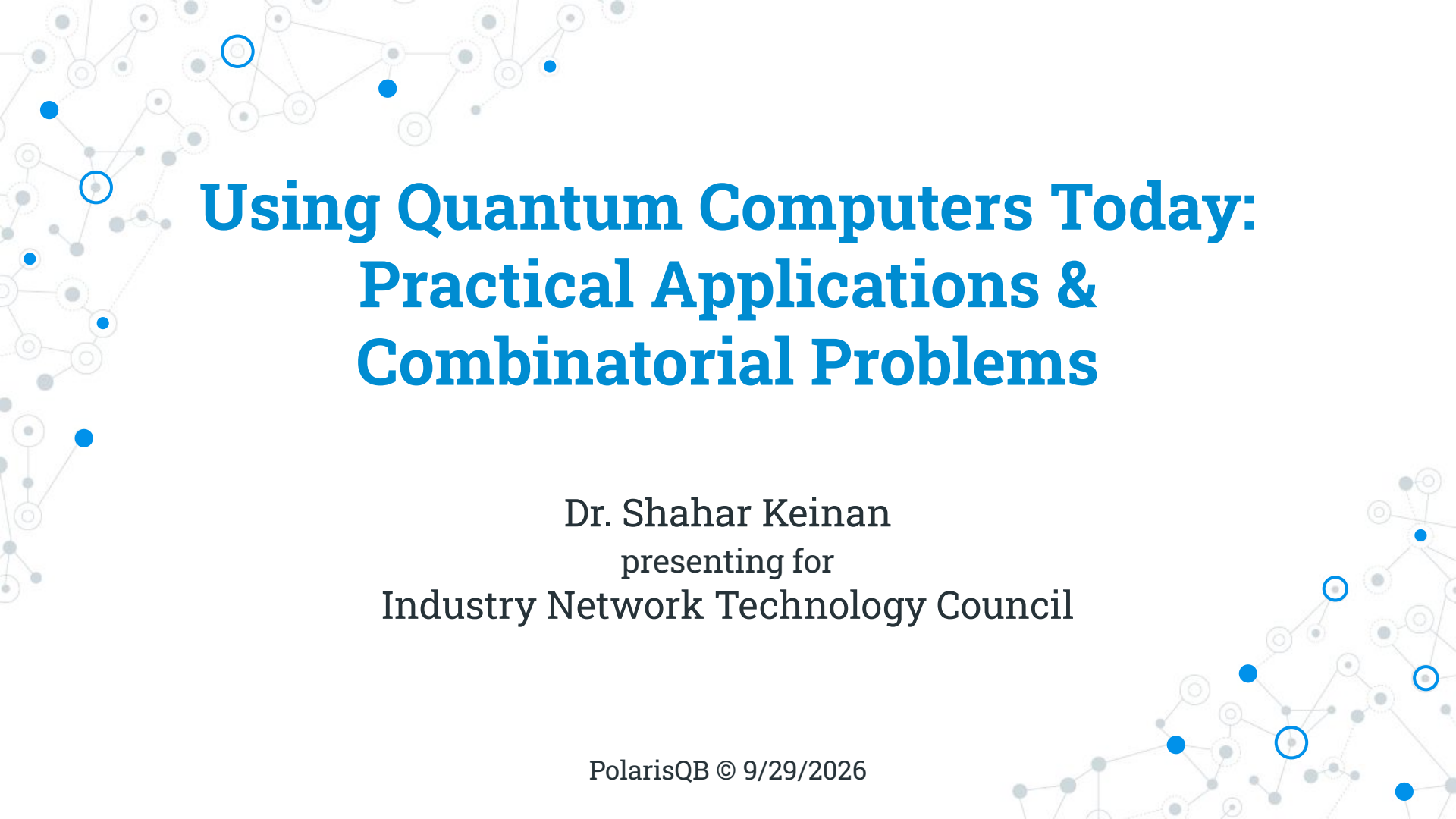




Using Quantum Computers Today: Practical Applications & Combinatorial Problems

Dr. Shahar Keinan
presenting for
Industry Network Technology Council



Dr. Shahar Keinan,
co-founder and CEO, Polaris Quantum Biotech

- Ph.D. in comp. Chem., The Hebrew University of Jerusalem
- Post doc in Northwestern University, then Duke
- Short stint: Researcher @ UNC-CH
- CSO & Co-founder Cloud Pharmaceuticals (2010-2019)
- Co-founder PolarisQB 2020

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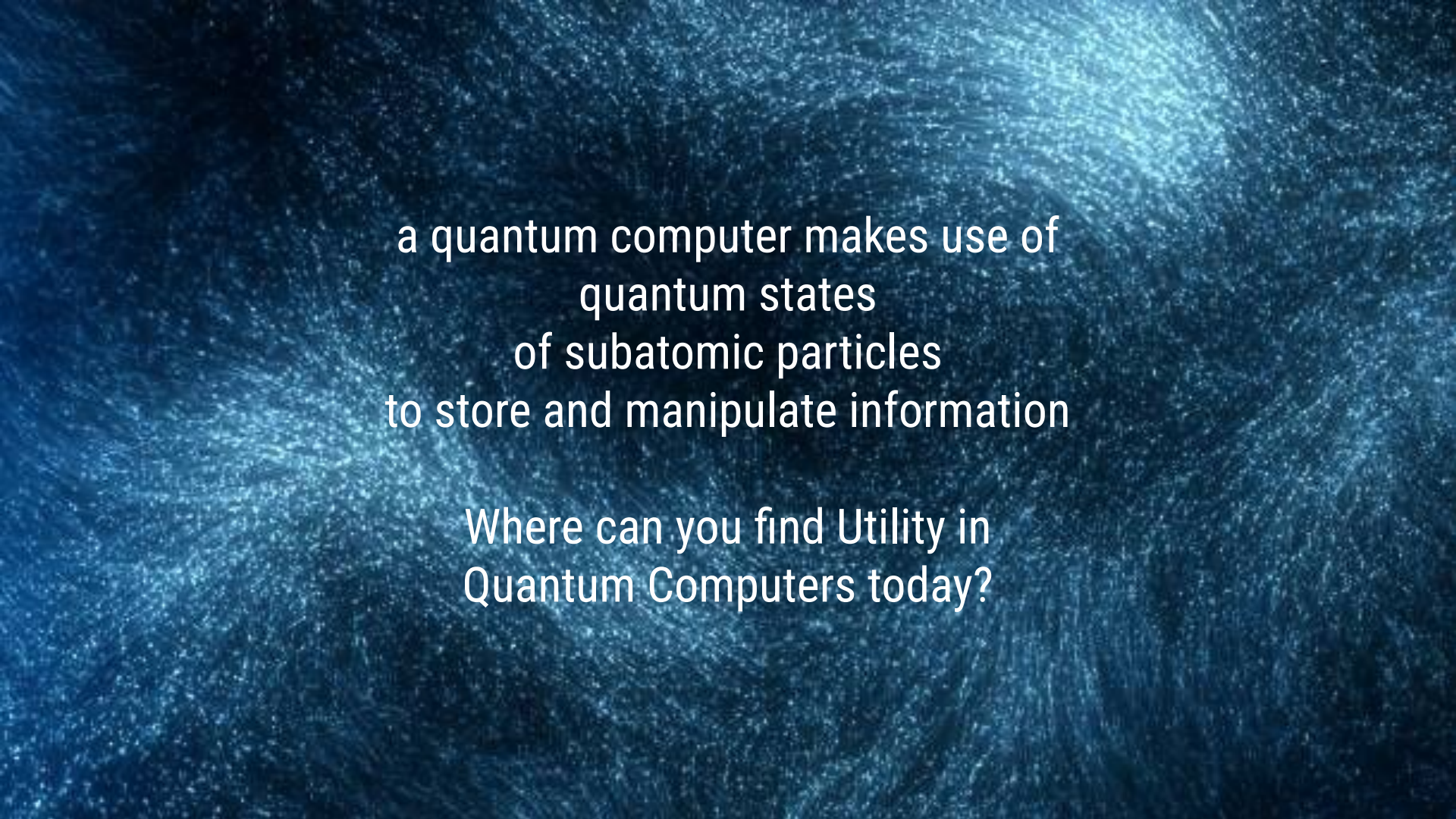




Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy.

— *Richard P. Feynman*

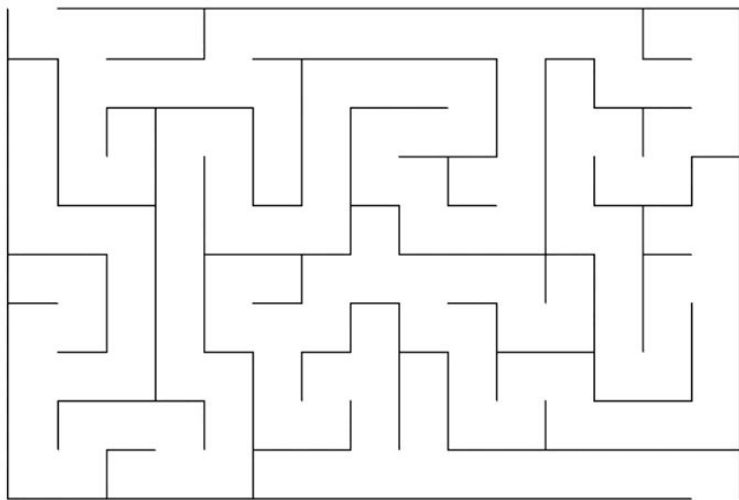
AZ QUOTES



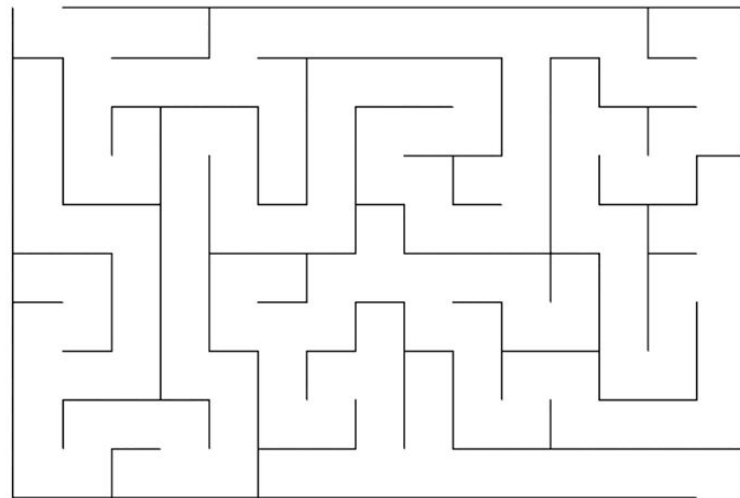
a quantum computer makes use of
quantum states
of subatomic particles
to store and manipulate information

Where can you find Utility in
Quantum Computers today?

Quantum Computers solve problems differently



Conventional Computer



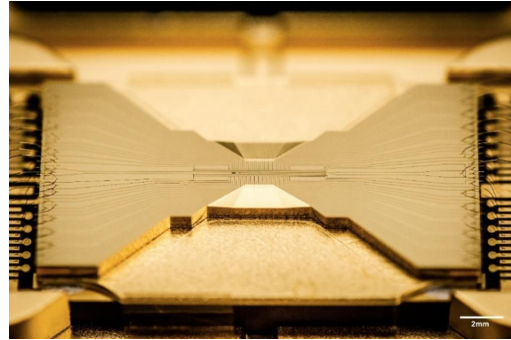
Quantum Computer

Image Credit to [Chuck Bates](#) ⁽¹⁾

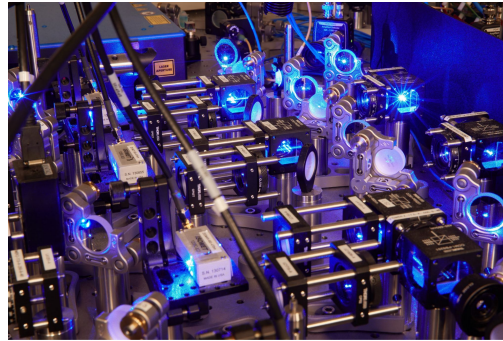
Commercially Available Quantum Computers



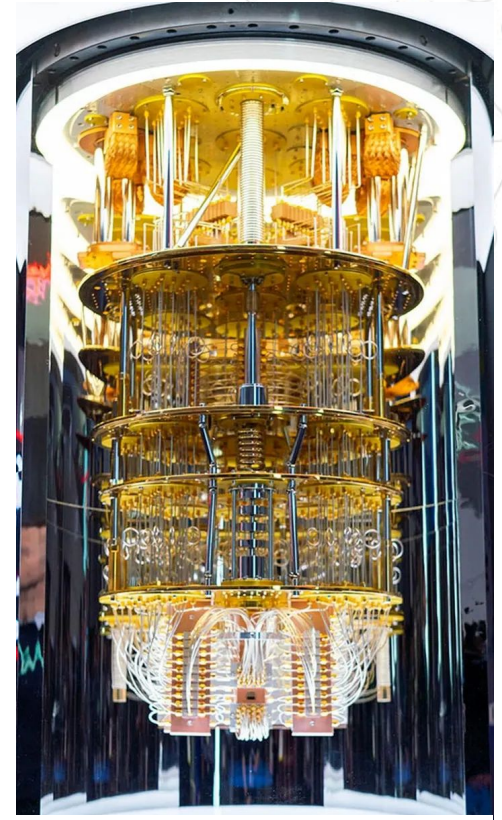
D-Wave Advantage Quantum Annealer



IONQ's Ion Trap Chip



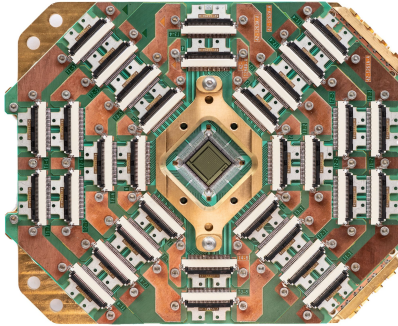
QuEra's Neutral Atom QC



IBM's QC

Different kinds of Quantum Computers (A very limited view)

Quantum Annealers



- Optimization type problems only
- Large systems (4-10K qubits)
- Fujitsu, D'Wave etc

Gate Quantum Computers

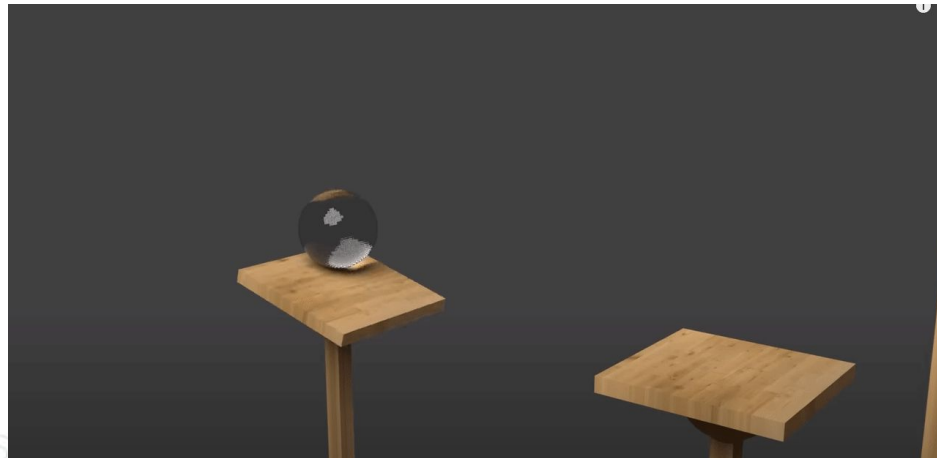


- All QC problem types
- Small systems (352 qubits)
- IBM, Google, Rigetti, IonQ

Two types of quantum computers:

Quantum Gate

Control and manipulate quantum state



Quantum Annealing

Optimization



	FACTORING	SIMULATION OF QUANTUM PHYSICAL PROCESSES	UNSTRUCTURED SEARCH	OPTIMIZATION
algorithm	Shor's factor large numbers exponentially faster, significant future threat to current encryption methods	Schrodinger's find the low energy state of a find the low energy state of atoms and molecules	Grover's finding a specific element in an unsorted database or list, where there's no inherent structure to exploit	Annealing search space is discrete with many local minima. a describable energy function that is purely additive in nature (for current architecture)
when relevant	Factoring a 2048-bit RSA key require 10^6 qubits	Over 10K qubits	Bigger QC solve bigger problems	AVAILABLE TODAY
use cases	cryptography	chemistry, nanotechnology, drug design	data retrieval, and optimization problems	optimization

Why Quantum?

- Quantum Computing solves ultra-large-scale optimization and simulation problems that are too complex for traditional computers
- May crack encryption, speed up decision-making in financial transactions, and improve AI/ML.

Gate Quantum Computers

- However, Gate Quantum Computers are still small (<1000 qubits) and are still in development
- Current industry estimates are 3-5 years from Gate Quantum Computers production-ready systems

**Today, only utility
can be found in
Quantum Annealers**

Quantum Advantage vs. Quantum Utility

- Reminder: Any problem that can be solved by a quantum computer can also be solved by a classical computer, at least in principle given enough time.
- “Quantum supremacy”: The ability to quickly solve certain problems that no classical computer could solve in any feasible amount of time
- “Quantum Advantage”: the milestone where a programmable quantum device or computer solves a practical problem faster, more efficiently, or more accurately than the best available classical supercomputer
- “Quantum Utility”: Solving a problem on a quantum computer today, faster and more efficiently than using a classical computer

REMINDER: Cyber Security is the main reason why everyone should think about QC

- Post-quantum cryptography (PQC), the quantum threat
- The problem:
 - Currently popular security algorithms (encryption) rely on one of three hard mathematical problems: the integer factorization problem, the discrete logarithm problem or the elliptic-curve discrete logarithm problem.
 - All of these problems can be easily solved on a sufficiently powerful quantum computer running Shor's algorithm
- The conversation today is no longer about whether it is necessary to implement PQC, but how to do so, and when.
- Because of “harvest now-decrypt later” hacking strategies, the quantum threat is increasingly seen as immediate.

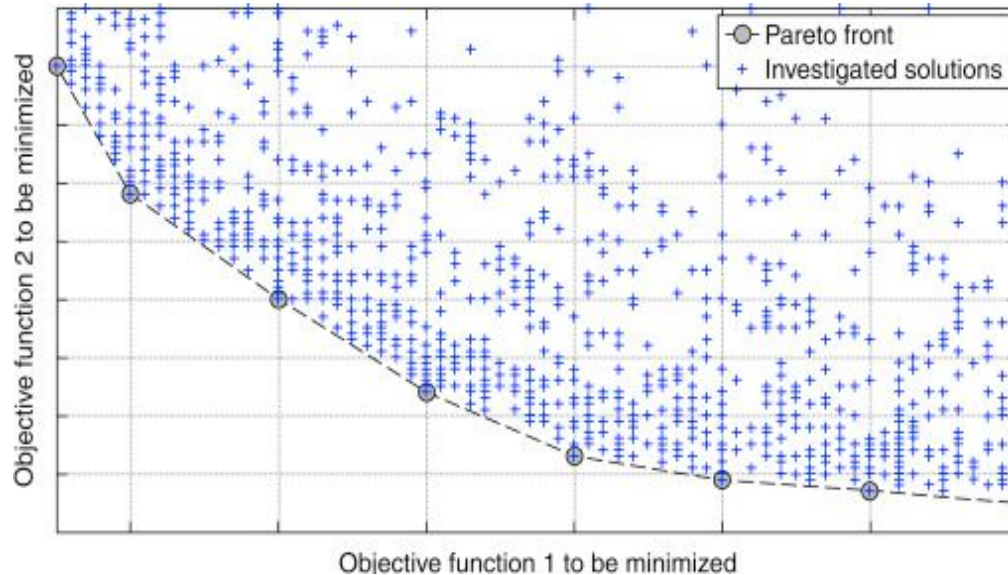
The background is a deep blue, almost black, with intricate, swirling patterns of lighter blue and white. These patterns resemble smoke, water currents, or perhaps a microscopic view of a fluid. There are several bright, out-of-focus light sources or 'stars' scattered across the field, with the most prominent one in the upper right corner. The overall effect is one of dynamic movement and depth.

Quantum Annealers

Solving large optimization problems

- Quantum annealers can also be applied to optimize complex operational challenges
 - Supply chain logistics optimization
 - Scheduling of personnel/resources
 - Clinical trials: sites, patients stratification
 - Portfolio balancing
- Examples for supply chain optimization:
 - Faster and Better Route Optimization
 - Efficient Warehousing and Inventory Management
 - Enhanced Demand Forecasting and Risk Management
 - Real-Time Decision Making

The benefits of using Quantum Annealers: Solving a multi-paramaters optimization problem



A Pareto front is the set of all solutions that are considered "non-dominated" to a multi-objective optimization problem. Each solution on the Pareto front represents a unique trade-off among objectives: improving one aspect of the solution will necessarily worsen at least one other aspect.

Quantum Annealers commercial utility today

Quantum Optimization: Applications Driving Operational Excellence

Retail



80% Increase in Scheduling Efficiency

Manufacturing



1,000 Vehicles Scheduled Per Run in 5 vs. 30 Min

Field Service Operations



Network Optimization Workloads From 1 hour Down to <15 seconds

Chemical



Scheduling Time Reduced From 10 Hours to Just Seconds

Asset Utilization



15% Improvement in Mobile Network Performance

Public Sector



Optimized Placement of Police Vehicles for Faster Response

Body Shop Scheduling

FORD OTOSAN



Faster
PRODUCTION
SEQUENCING FOR
1000 VEHICLES

PROBLEM

Ford Otosan, a joint venture between Ford Motor Company and Koç Holding in Turkey, sought greater efficiency in the body shop for the Ford Transit line of vehicles.

SOLUTION

The company created a hybrid quantum application to optimize vehicle production sequencing in the body shop that minimized downtime, maintained efficiency and addressed the need for real-time decision making.

OUTCOME

Solution reduced scheduling time of **1,000 vehicles per run from 30 minutes to less than five**. It also offered more flexibility to adapt to changes in demand or auto part availability.

MOBILE NETWORK OPTIMIZATION

NTT
docomo

15%

MORE
NETWORK
CAPACITY

PROBLEM

NTT DOCOMO, Japan's largest mobile phone operator, wanted to reduce congestion at base stations during peak calling times.

SOLUTION

The company used D-Wave's hybrid-quantum technology to optimize base station tracking areas.

OUTCOME

The solution identified mobile network performance improvements that could **reduce paging signals during peak times by 15%**; the company now has plans to deploy across its Japanese branch offices.

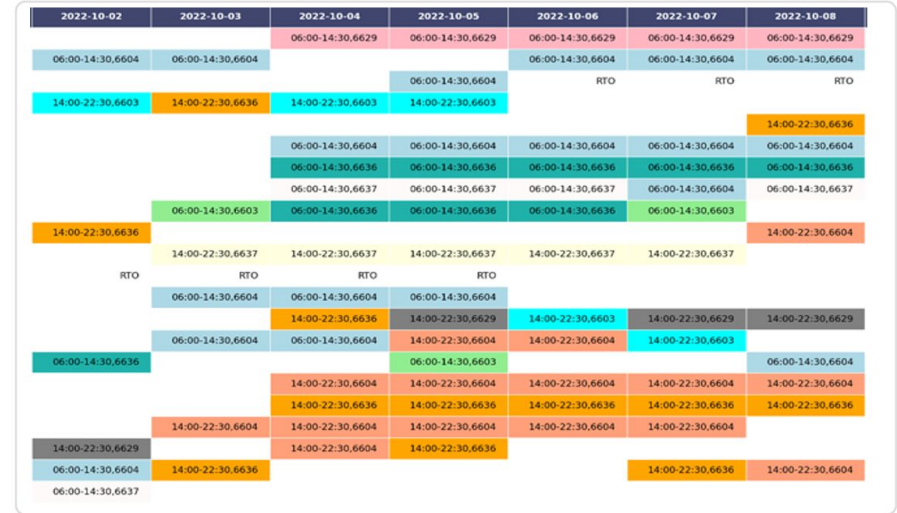
Vehicle Routing & Complex Employees Scheduling

- The Pattison Food Group (PFG) collaborated with D-Wave
- PFG is the largest purveyor of food and healthcare products in western Canada, with more than 100 retail locations offering online ordering
- Until recently, managing the driver schedules for those orders was a manual task



Vehicle Routing & Complex Employees Scheduling

- This is Multi-object optimization problem:
 - Mapping out each worker's weekly availability
 - Which stores a given driver is willing and able to get to
 - How many drivers are needed on each shift
 - Ensure that time between each shift is at least 10 hours
 - Other considerations
- The number of variables and constraints contribute to the complexity of developing optimal schedules.



CALGARY NORTH EXAMPLE: Each schedule is based on an area that covers 1 or more stores. Max and Min number of shifts as well as TM is respected.



Vehicle Routing & Complex Employees Scheduling

- The Pattison Food Group (PFG) collaborated with D-Wave
- Success was measured by a number of metrics, including:
 - The ability to meet a threshold of 95% of the demand from the company's e-commerce shoppers
 - Ensuring that drivers routinely received schedules that fulfill their expectations.
- As of today, each of the 100+ stores offering online ordering are consistently meeting these objectives.
- Furthermore, the auto-scheduler is saving both time and effort, trimming what was once an 80-hour task to just 15 hours each week, an 80% time savings.

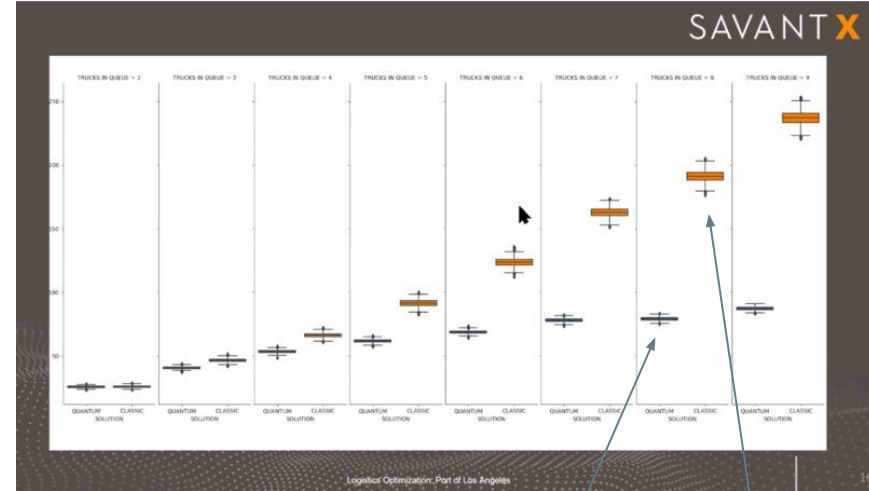


An aerial photograph of the Port of Los Angeles. The image shows a large body of water with several piers and docks. A large ship is docked at a pier on the right. In the foreground, a speedboat is moving across the water, leaving a white wake. The background shows a dense urban area with many buildings and a large green field. A semi-transparent grey box with white text is overlaid on the center of the image.

SavantX doubled
the efficiency of
cranes on pier
300 at the The
Port of Los
Angeles

SavantX @ Port of Los Angeles

- Port of Los Angeles/Long Beach, is the United States' busiest port
- Challenges include as excessive wait time, too many touches of containers, and excessive crane maintenance can occur.
- SavantX used D-Wave's 2000 QPU, with 100K runs of simulations of 1 million data points over 1 month
- Results: quantum consistently outperformed on trucks in the queue vs the number of feet on average of crane movement



Quantum

Classic

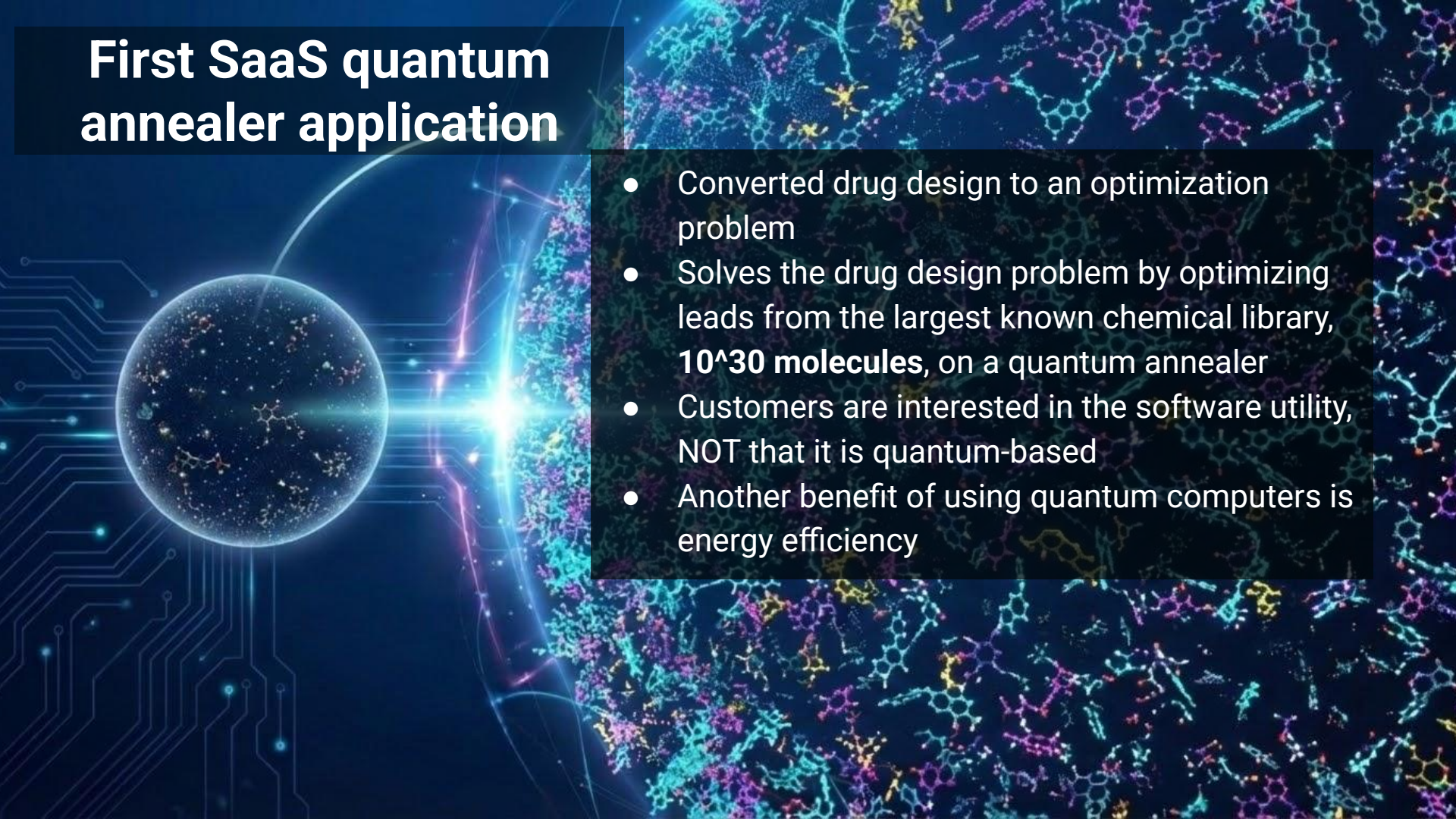
Quantum-South: Air Cargo Optimization Application

- Optimizing how air cargo should be loaded optimally into a freighter aircraft
- Must take into account revenue, priority, center of gravity, shear force and volume, weight and balance restrictions.
- A complicated Knapsack Problem
- Quantum-South has now application ready for production use with popular Airbus A330-200F or Boeing 747-400 air freighters running on D'Wave



Computational drug design

First SaaS quantum annealer application

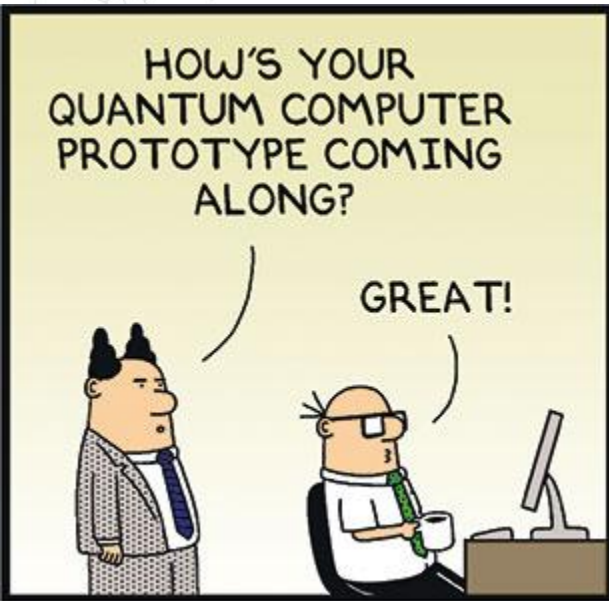


- Converted drug design to an optimization problem
- Solves the drug design problem by optimizing leads from the largest known chemical library, **10^{30} molecules**, on a quantum annealer
- Customers are interested in the software utility, NOT that it is quantum-based
- Another benefit of using quantum computers is energy efficiency

Energy Efficiency

- Comparison to classical methods:
 - To run 10 targets on the Summit supercomputer for 1 month straight costs ~2 million dollars (or \$444K academic pricing)
 - To run 10 targets on QuADD powered by D-Wave's Advantage only take 5 compute hours (less than 5 minutes on the D'Wave system)
- Comparison to AI-based methods:
 - QuADD ran 80× faster (~30 minutes vs. 40 hours) than BInD





My life is a quantum project...



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THE PROMISE OF
QUANTUM UTILITY.

TODAY

