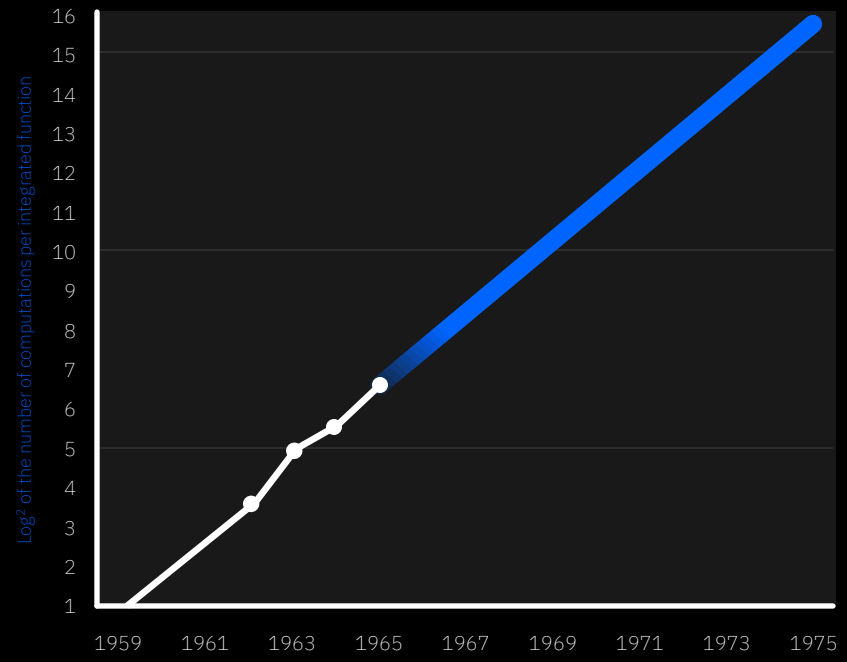
Quantum Computing challenges for EDA.

—

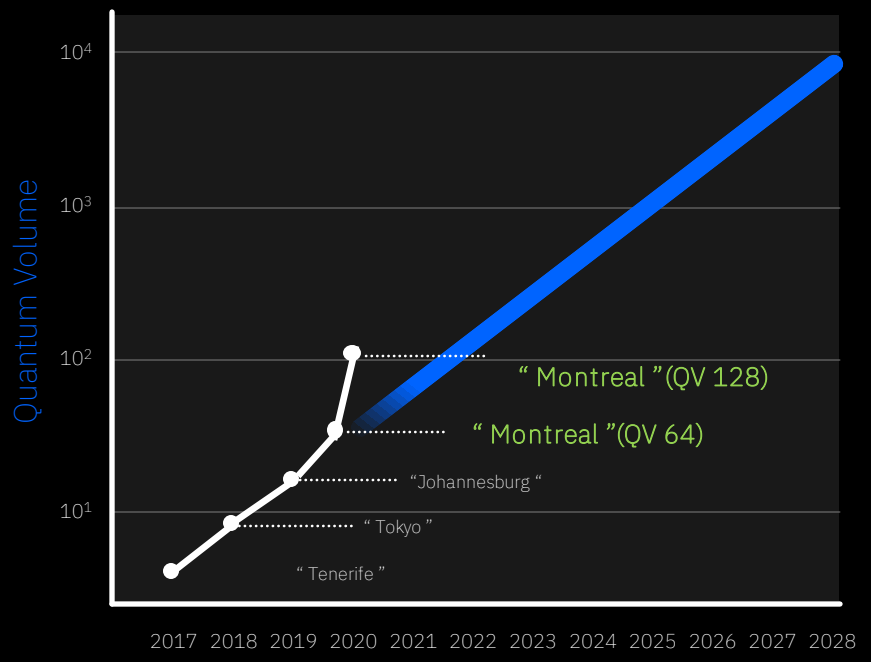
Dr. Leon Stok
VP – EDA
IBM

We are in the early stages of a rapidly advancing new computing technology

Moore's law



Quantum Volume: The New Moore's Law



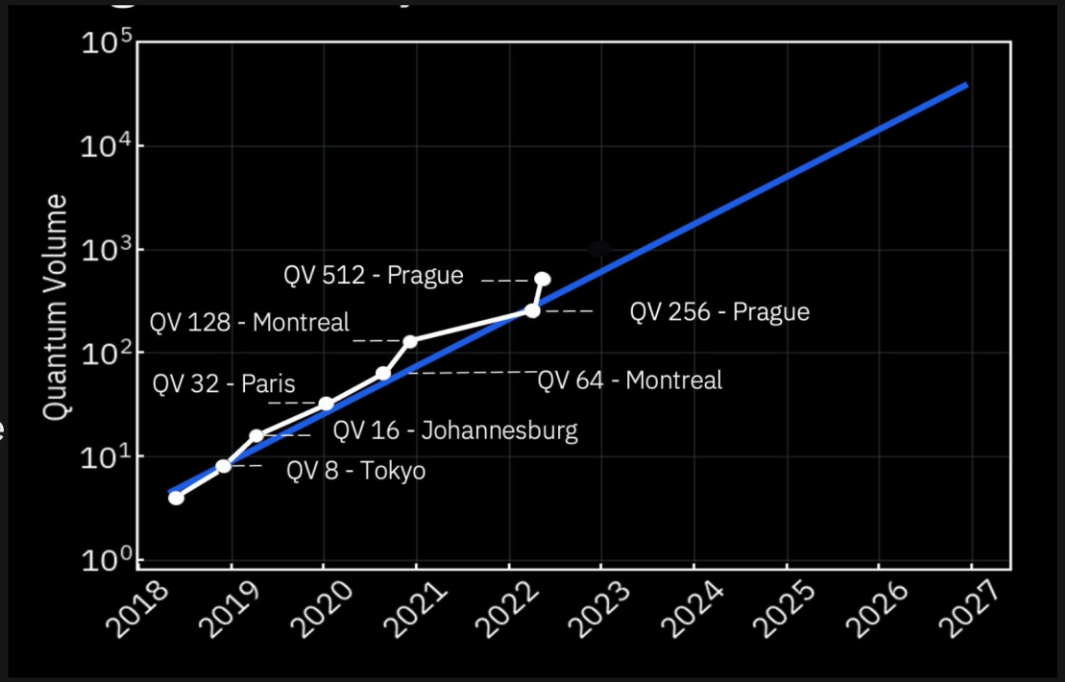
Ahead of the curve on quality

IBM **Quantum**

We have committed to doubling quantum volume every year. So far, we are a little ahead of pace.

Today, improvements largely come from improving physical error rates.

When we introduce quantum error correction, there will be an inflection point where Quantum Volume will increase much faster due to software (encoded) scaling.



 #IBMQ

Details

33
Qubits

512
QV

Status:	Online
Total pending jobs:	0 jobs
Processor type:	Falcon r10
Version:	2.0.0
Basis gates:	CZ, ID, RZ, SX, X
Your usage:	--

Median CZ Error:	4.373e-3
Median Readout Error:	1.320e-2
Median T1:	153.36 us
Median T2:	130.03 us
Providers with access:	--

Your upcoming reservations

Calibration data

Last calibrated: 2 days ago

Map view | Graph view | Table view

Qubit:

T2 (us)

Median 130.03

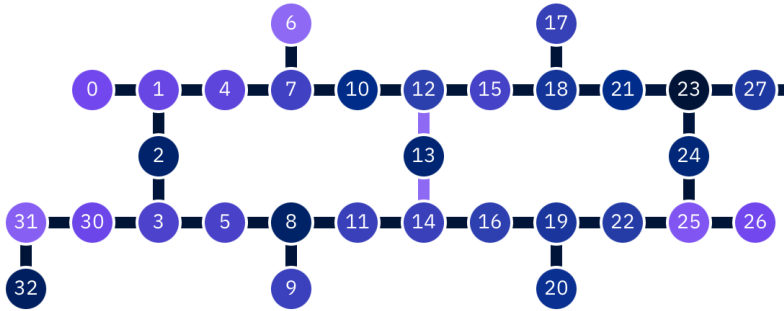
min 11.12 max 238.61

Connection:

CZ error

Median 4.373e-3

min 1.044e-3 max 1.000e+0



Quantum Computing a

The three key metrics for measuring quantum computing performance

Scale

Measured by **number of qubits** which indicates the amount of information we can encode in the quantum system.

High coherence, high reliability, lower cost

2020	2021	2022
65 qubits	127 qubits	433 qubits

Quality

Measured by **Quantum Volume** which indicates quality of circuits and how faithfully circuits are implemented in hardware.

Need low operation errors, meaning large Quantum Volume

2020	Today	2022
32 QV	512 QV	1024 QV

Speed

Measured by **CLOPS (Circuit Layer Operations Per Second)** which indicates how many circuits can run on hardware in a given time.

Seamless synchronization of quantum and classical circuits increases execution rate

2020	Today	2022
200 (Inferred)	1.4K CLOPS	10K CLOPS

Development Roadmap

Executed by IBM
On target

IBM **Quantum**

	2019	2020	2021	2022	2023	2024	2025	Beyond 2026
Model Developers					Prototype quantum software applications → Quantum software applications			
					Machine Learning | Optimization | Natural Science | Finance			
Algorithm Developers		Quantum algorithm and application modules			Quantum Serverless			
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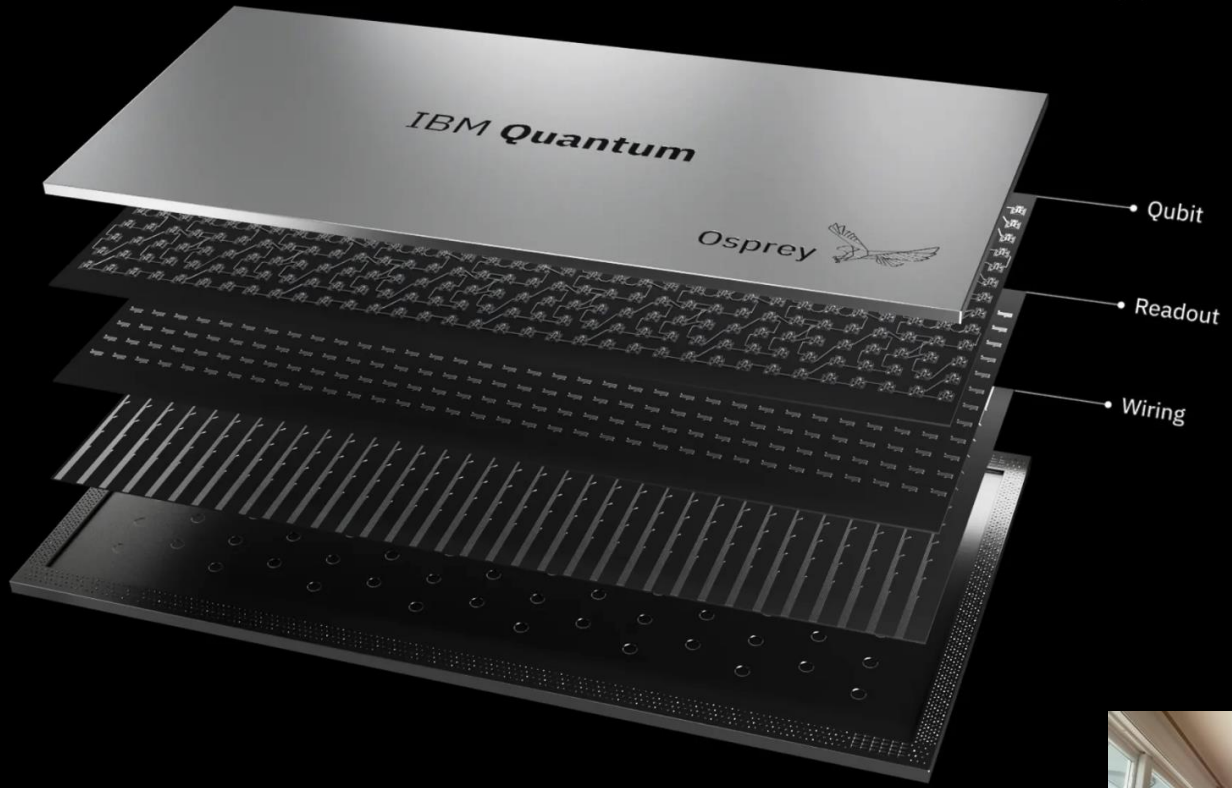
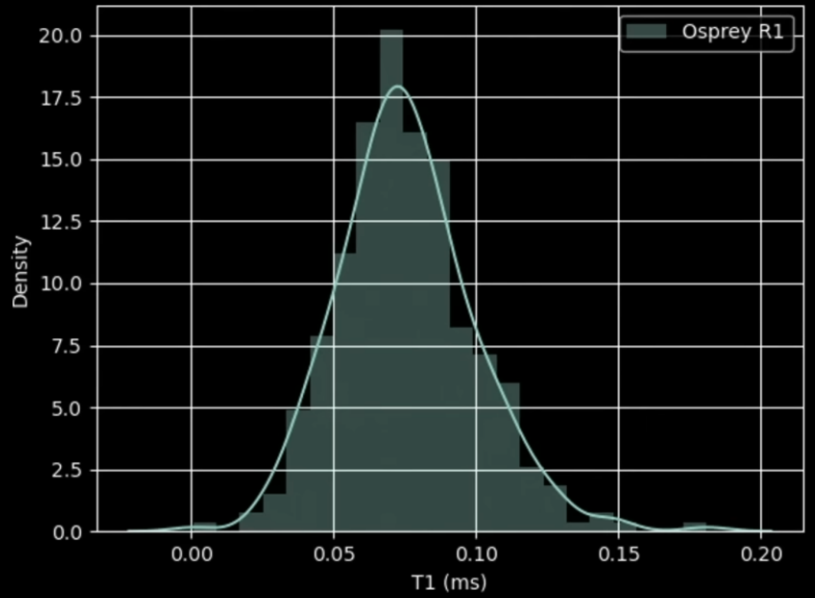
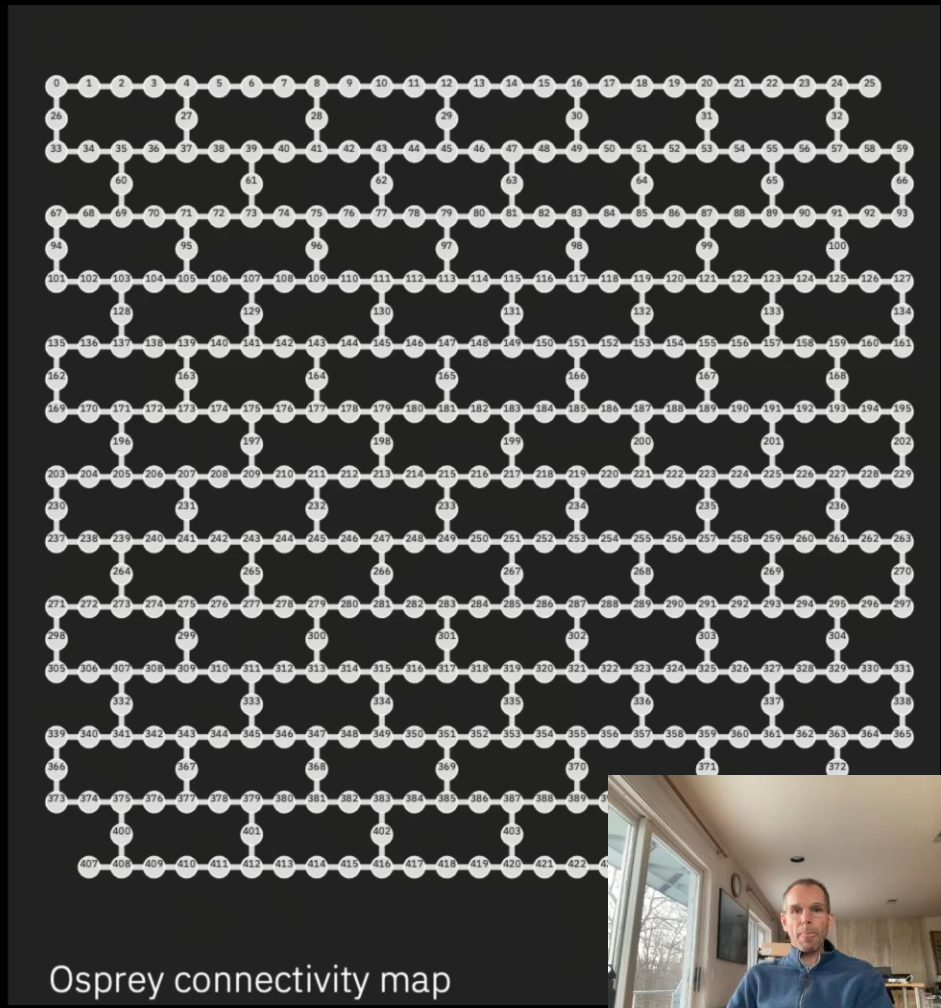
					Heron 133 qubits x p	Crossbill 408 qubits		


IBM Quantum
Osprey
Qubit
Readout
Wiring

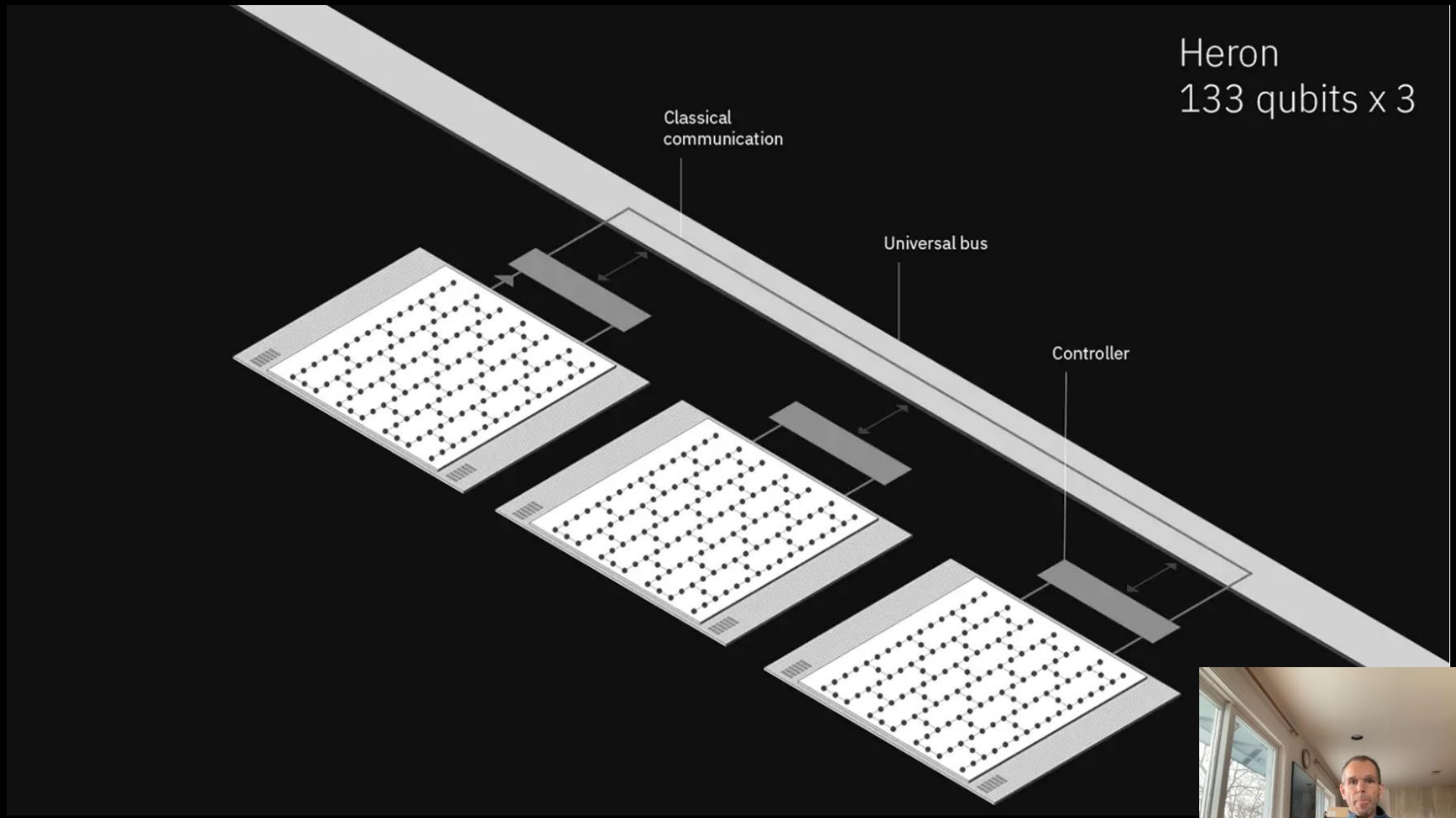
Osprey R1- First Results

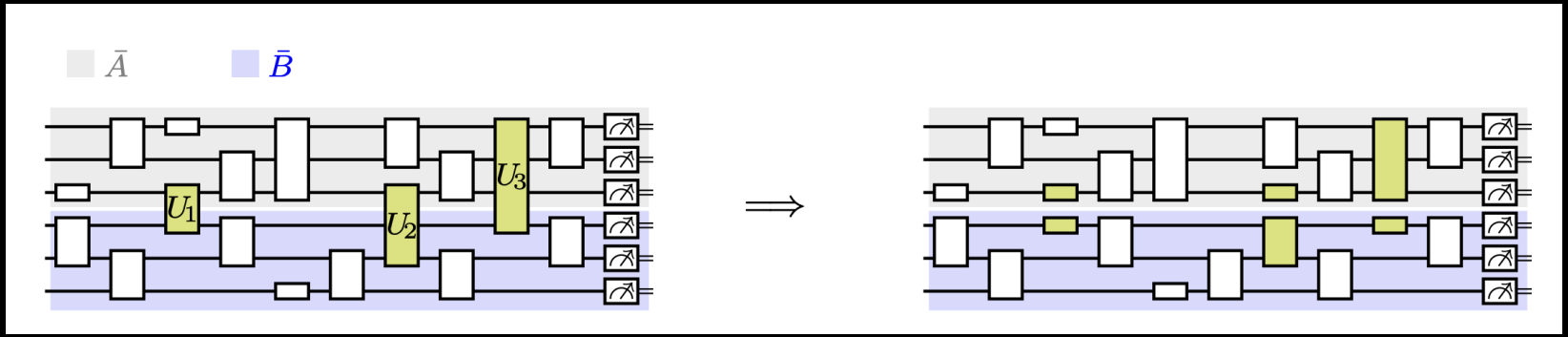


Median T1 73.5 μs



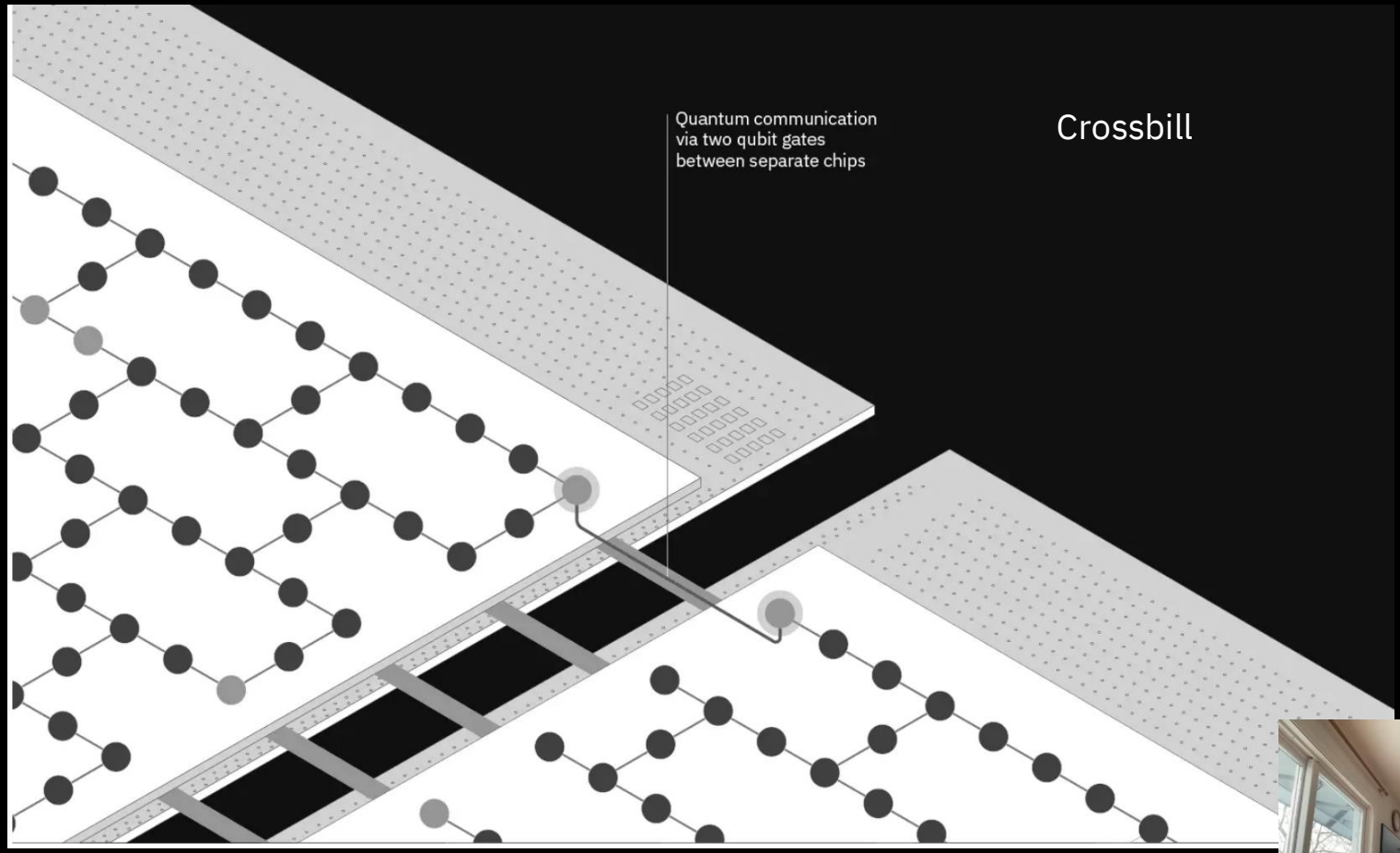
Osprey connectivity map


Heron
133 qubits x 3
Classical communication
Universal bus
Controller

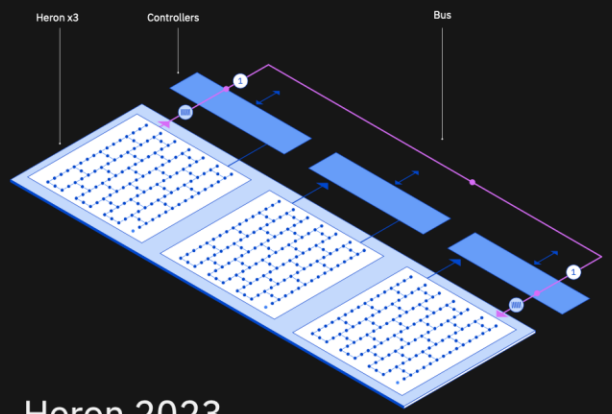


arXiv:2205.00016v1 [quant-ph] 29 Apr 2022

Circuit knitting with classical communication, Christophe Piveteau and David Sutter


Quantum communication
via two qubit gates
between separate chips

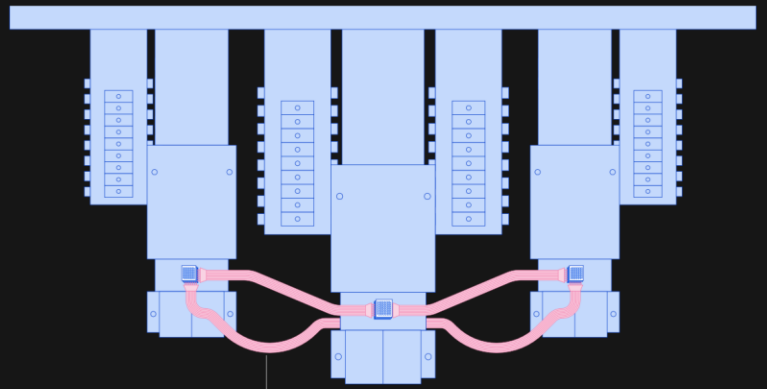
Crossbill



Heron 2023

133 qubits x p

Classically connected controller



Flamingo 2024

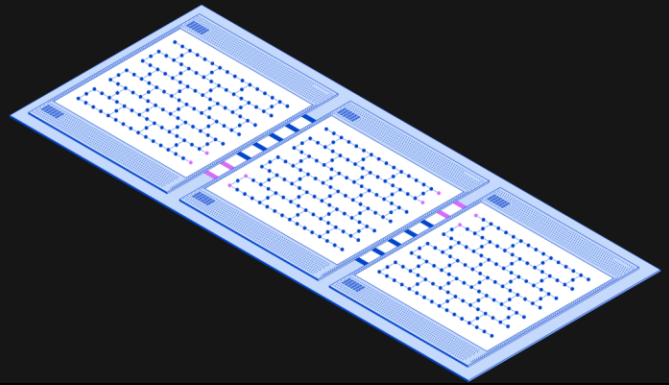
1386 qubits

Inter QPU quantum communications link

Crossbill 2024

408 qubits

Chip-to-chip modular quantum links



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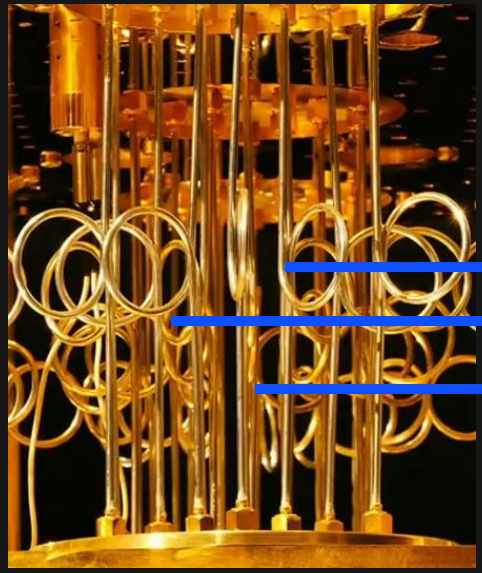
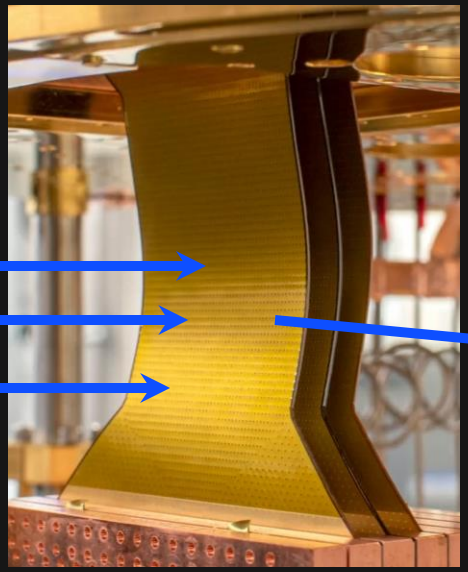
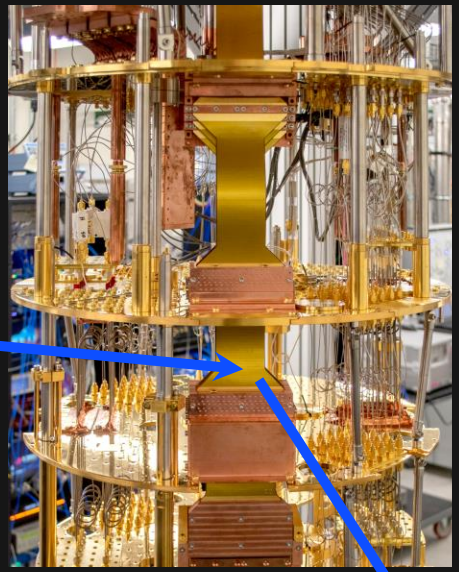
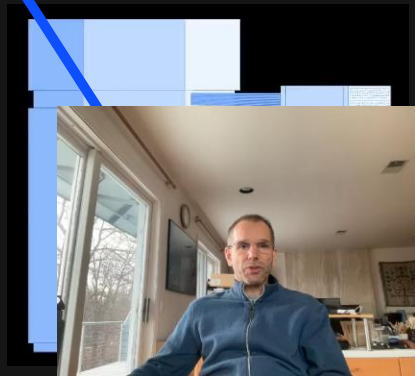
Quantum Breakthrough - Flex









Replace coaxial cables with flex wiring in cryogenic fridge

- 70% increase in wire density (scale)
- 5x reduction in price per line
- Customize with integrated components and materials

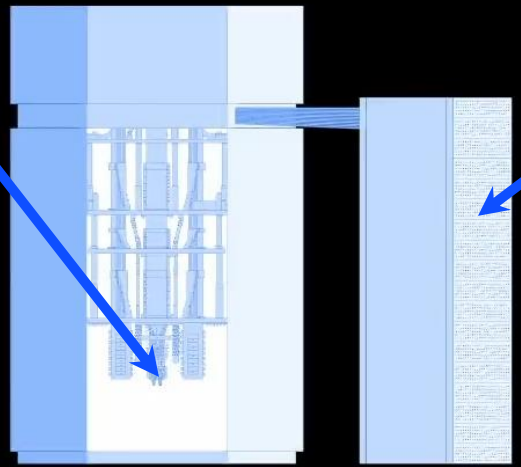
Quantum Breakthrough – Scale

Osprey Quantum processor

433 Qubits

3x Qubits !

Quantum system



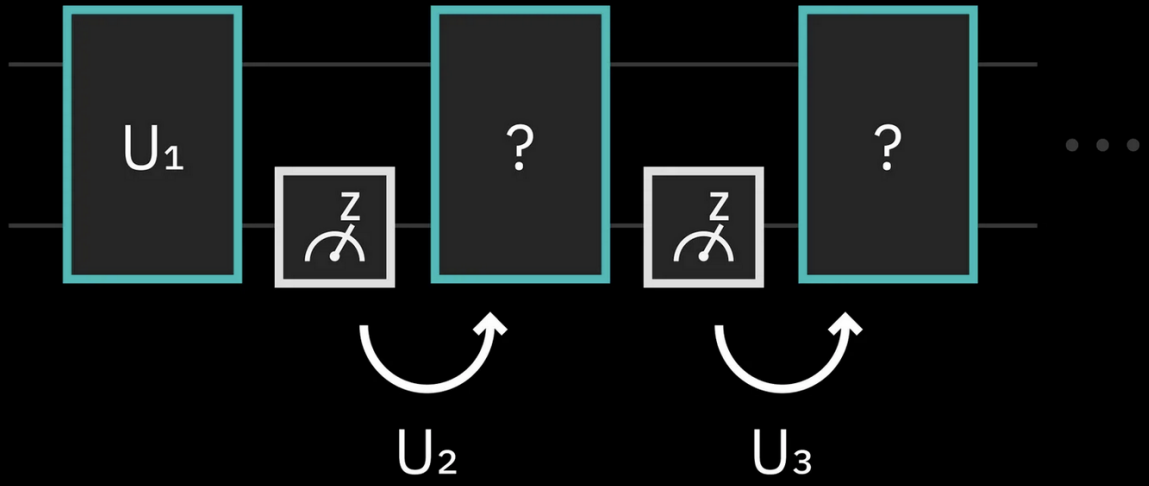
3rd Generation control system

Initialize and measure Qubits

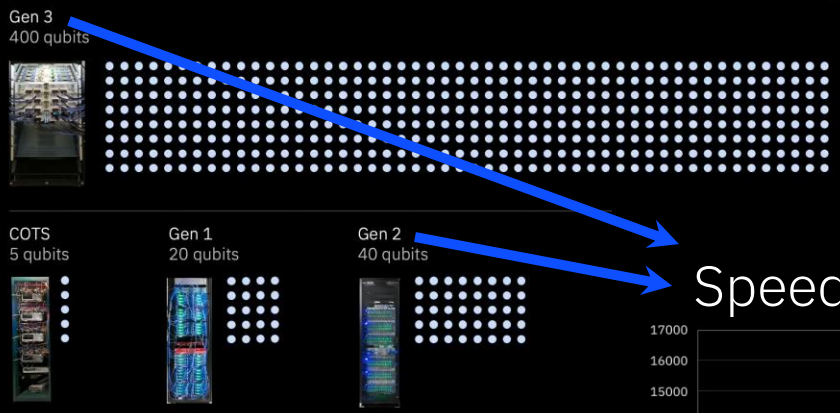
Dynamic circuit

Interface to cla

Dynamic Circuits

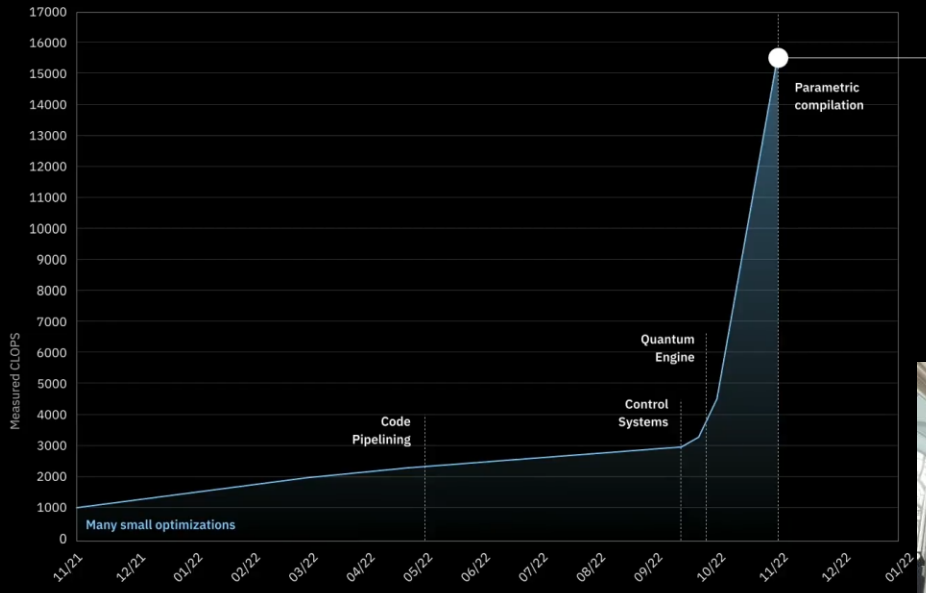


Quantum Breakthrough – Speed



10x Speed !

Speed Improvement



15,700
CLOPS

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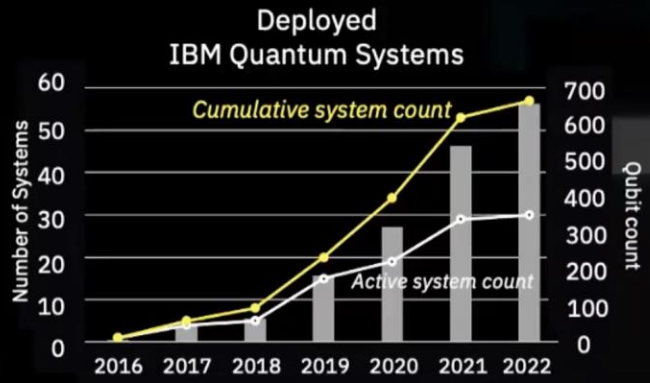
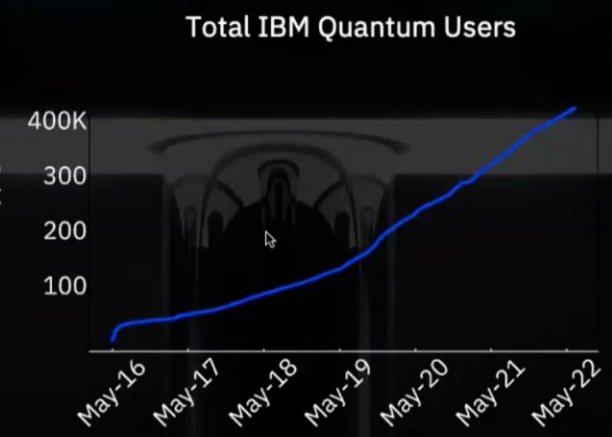
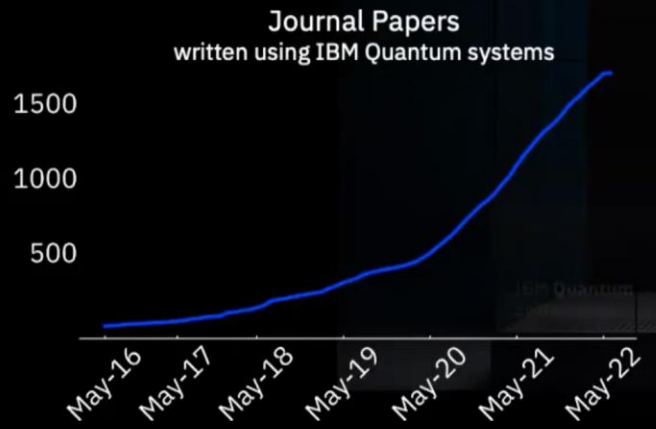
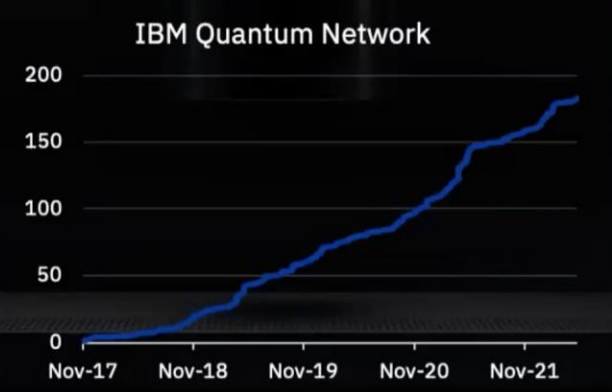
IBM Quantum by the numbers

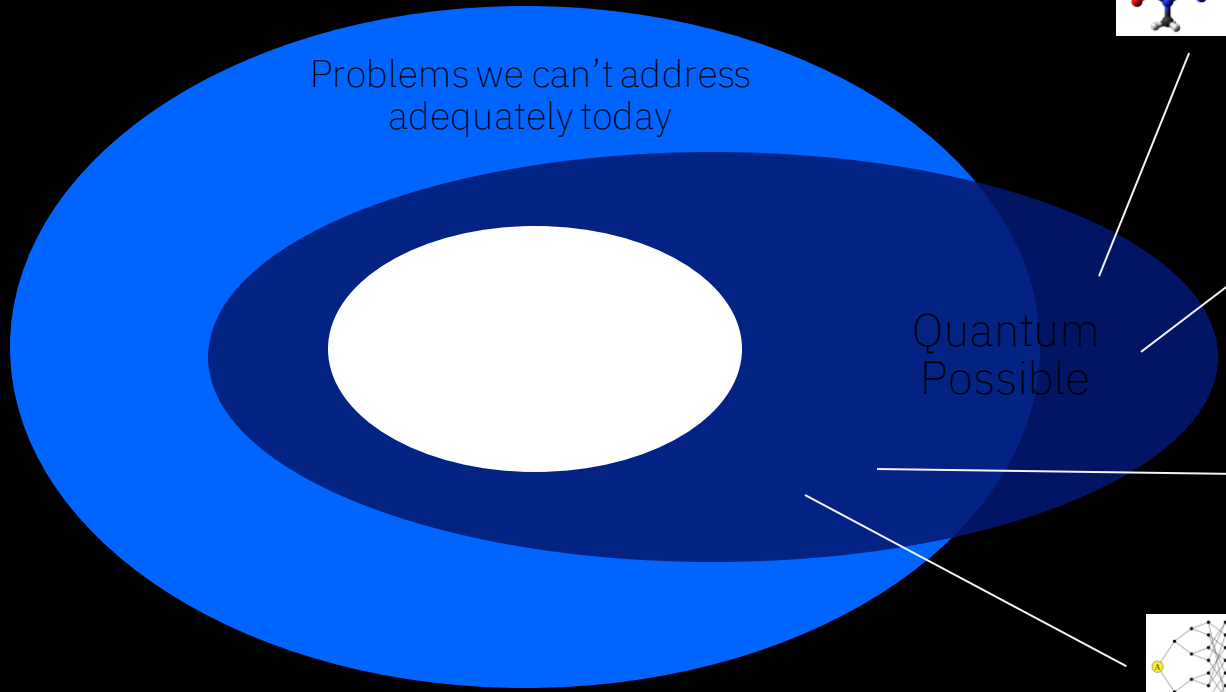








Quantum Computing Major Application Areas

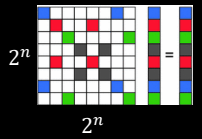


Quantum Simulation

Materials development
Chemistry/Physics
Device simulation

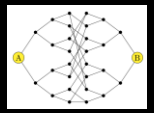
Machine Learning

Support vector machines
Neural networks
Generative-adversarial networks



Linear Algebra

Linear equation solving
Differential equations
Eigendecomposition



Optimization

SAT solvers
Combinatorial o
Monte Carlo sar

Education and Workforce enablement

460k+

Registered users have run 2.36 trillion circuits since 2016

12,000

Students attend QubitxQubit Intro to Quantum Computing

375+

Quantum computing courses using Qiskit

5M+

Learners accessing digital content