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FROM CHAOS TO COMMAND:
RISK LEADERSHIP IN INDUSTRY 6.0

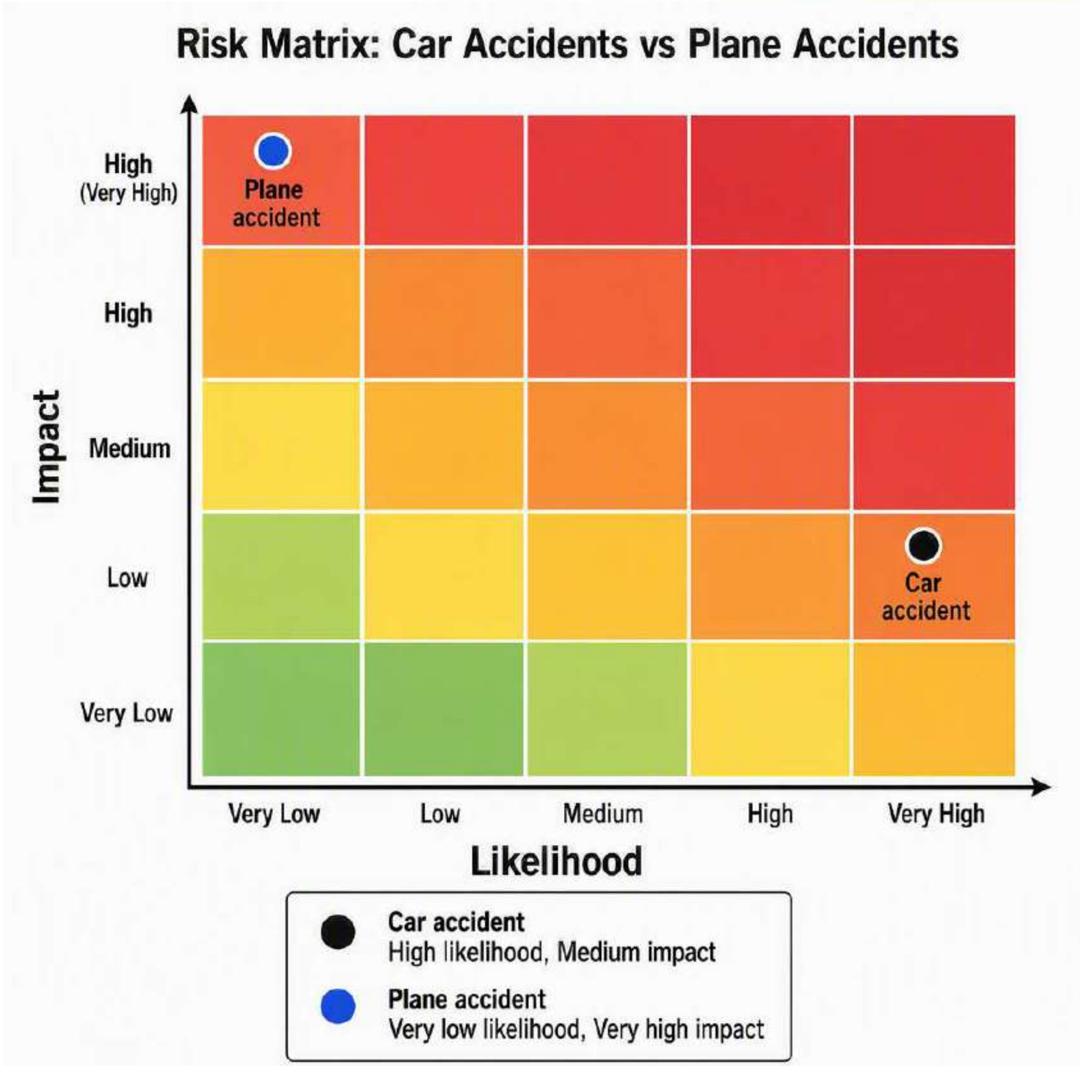
QUANTUM RISK AND THE ENTERPRISE: FROM THREAT TO STRATEGIC ADVANTAGE

Dr. Manas Mukherjee
Principal Investigator,
Centre for Quantum Technologies

Risk

Figure-of-merit quantification

Risk matrix



*AI assisted

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Case I

Kill or get killed by new technology

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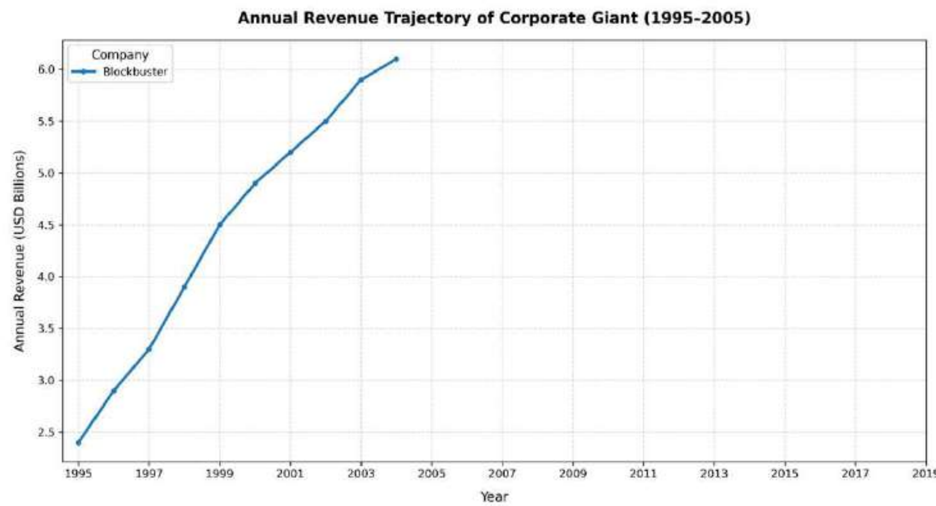
Video renting stores



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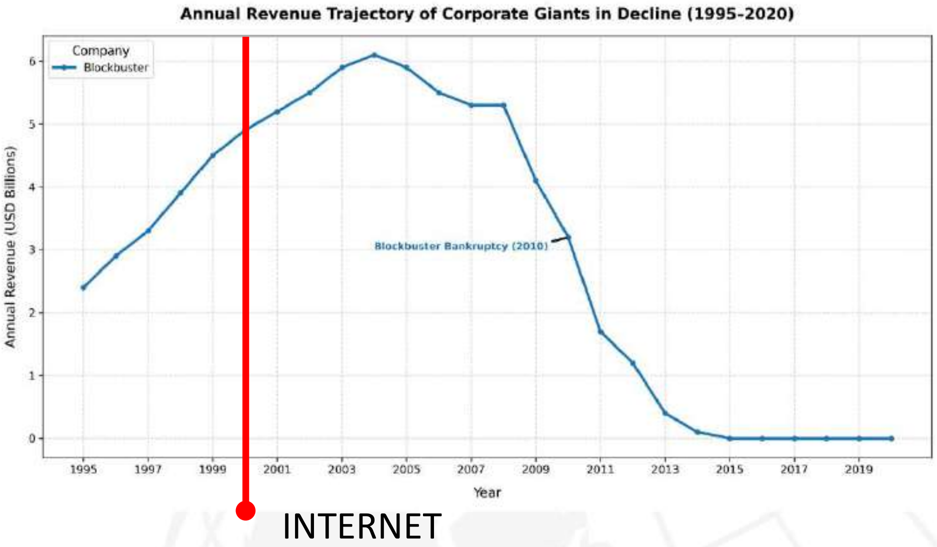
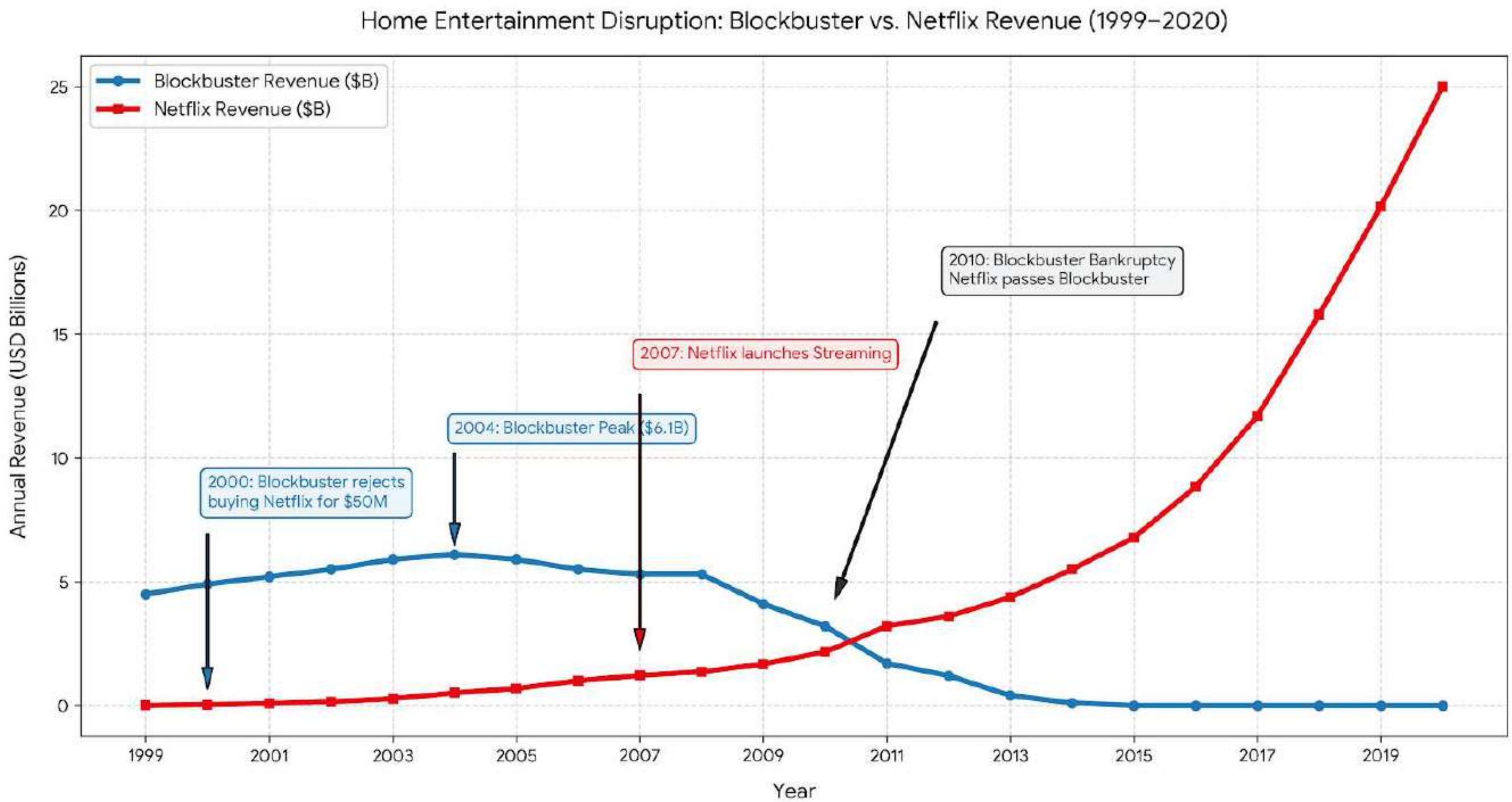
Video renting stores



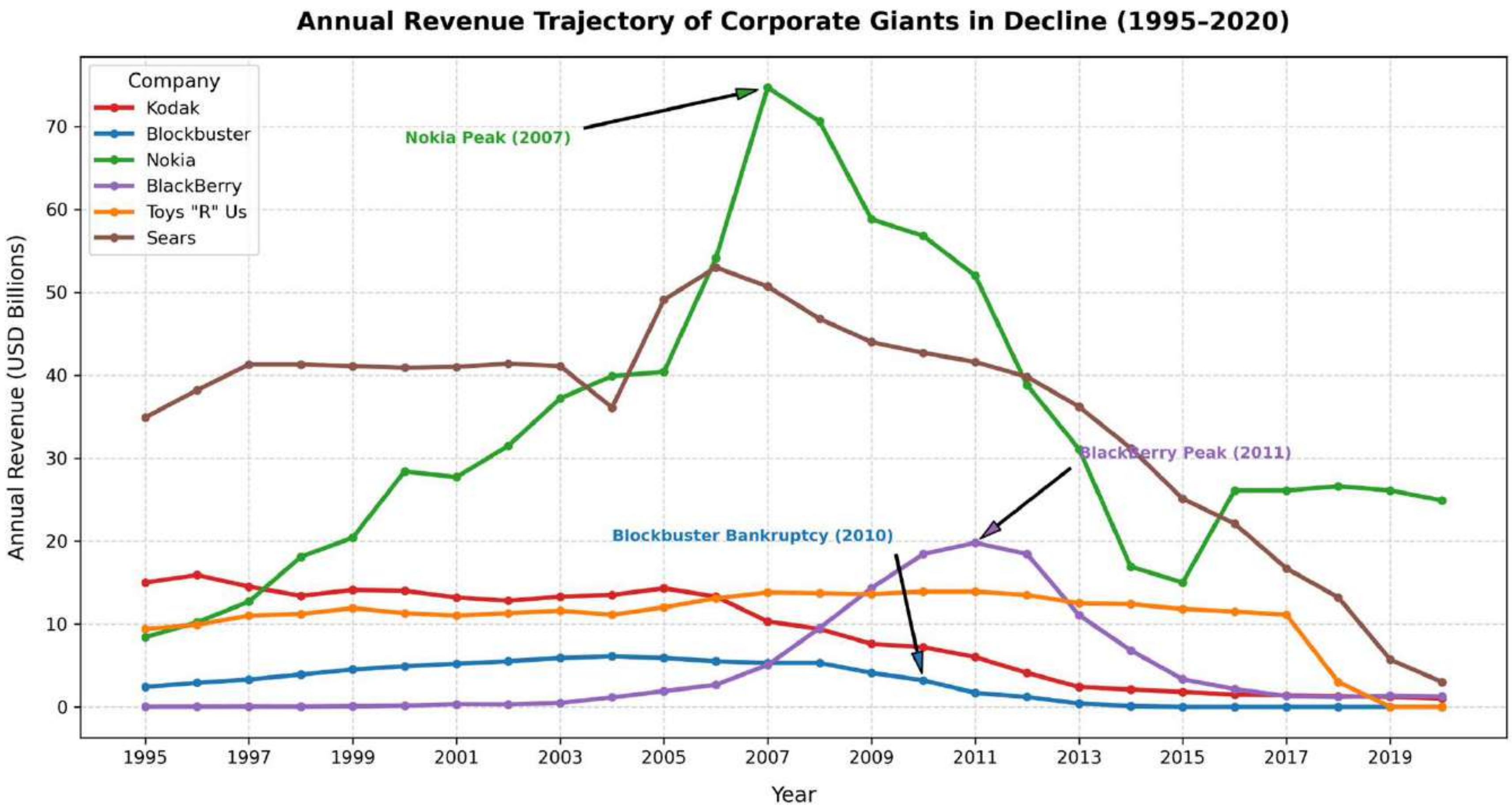
Why the decline?



Case N

Kill or get killed by technology

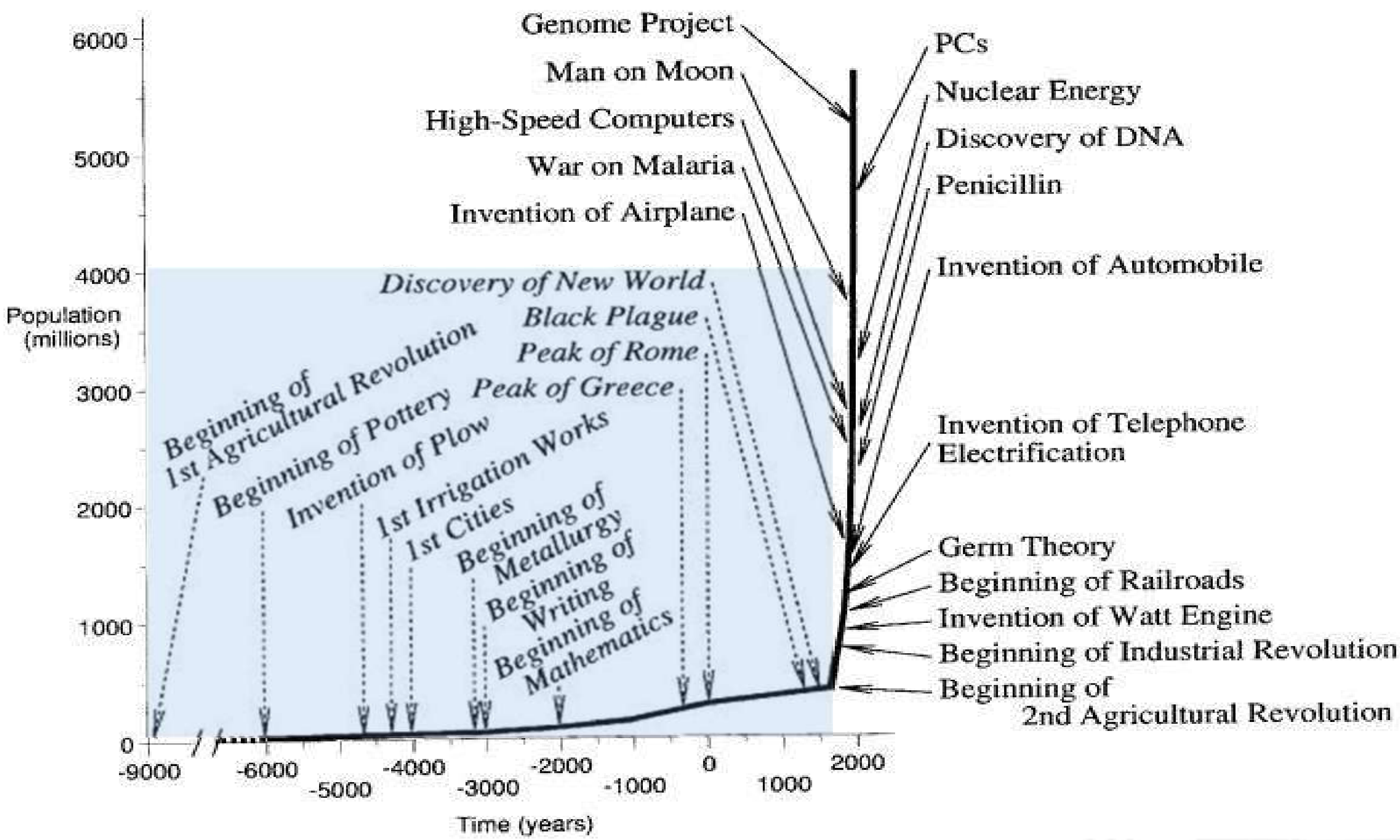
Forgot to learn from history



History repeats

Nokia	Delayed transition to touchscreen smartphones and modern app ecosystems
Sears	Neglected digital retail and supply chain tech in favor of physical store cuts
BlackBerry	Clung to physical keyboards and enterprise security while consumers demanded app ecosystems
Kodak	Hesitated to commercialize digital cameras to protect profitable film margins
Toys "R" Us	Surrendered digital infrastructure growth by outsourcing e-commerce to Amazon in 2000
Blockbuster	Rejected acquiring Netflix and relied on store late fees instead of digital streaming

Homo sapiens and their growth



"Catching Up with the Economy" By ROBERT W. FOGEL (1999)

Advent of the quantum era

International year of quantum science and technology 2025

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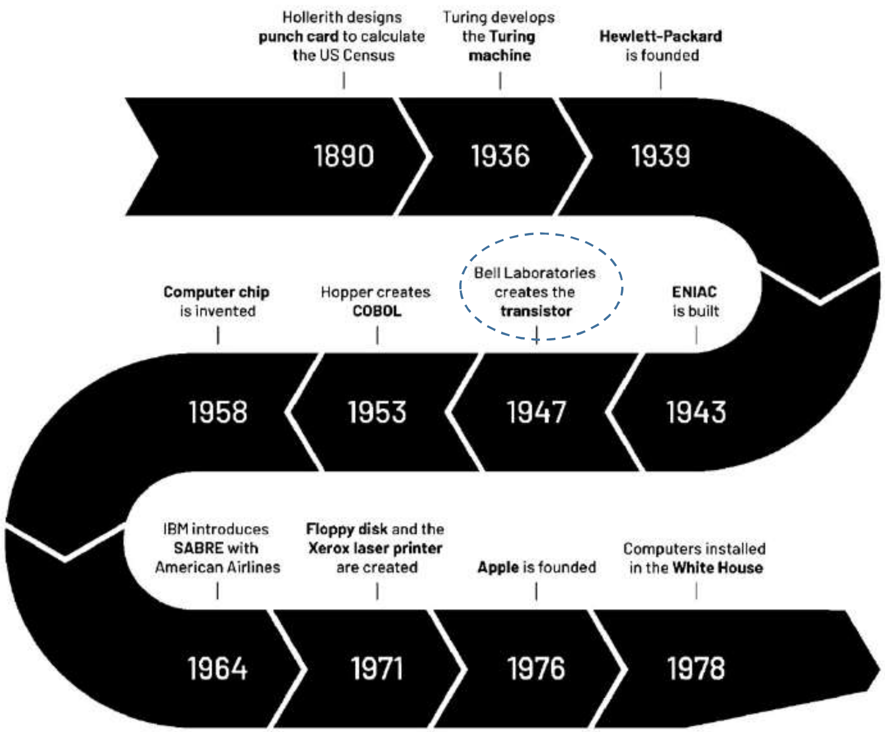
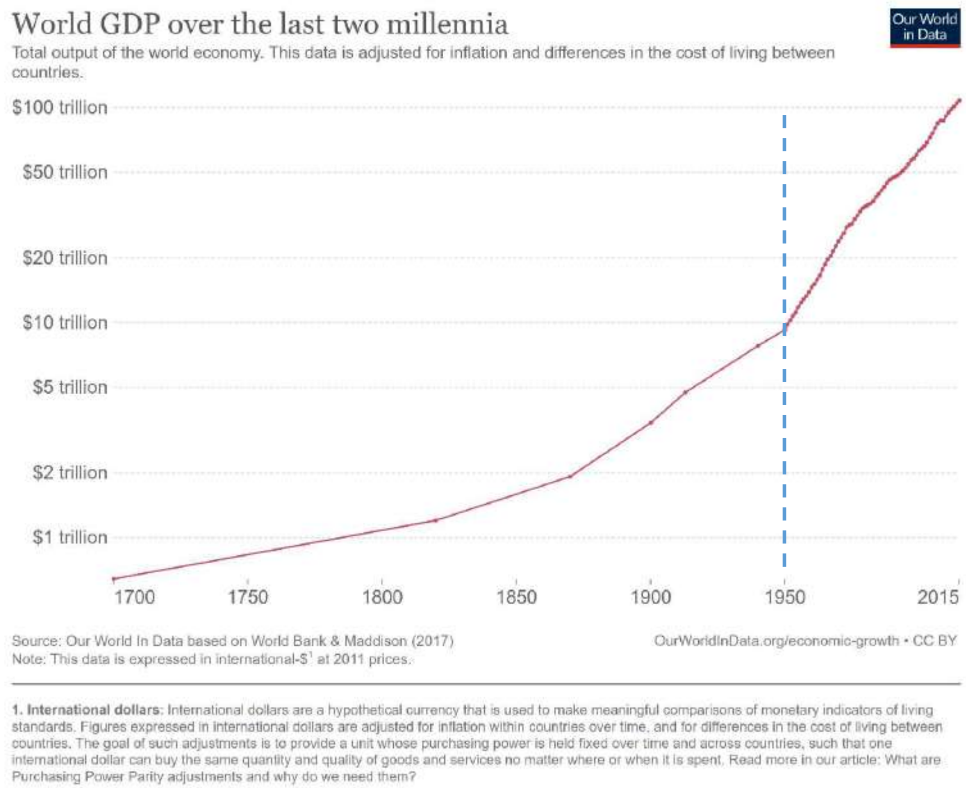
Semiconductor driven growth (Si-Age)





Our World in Data and g2.com

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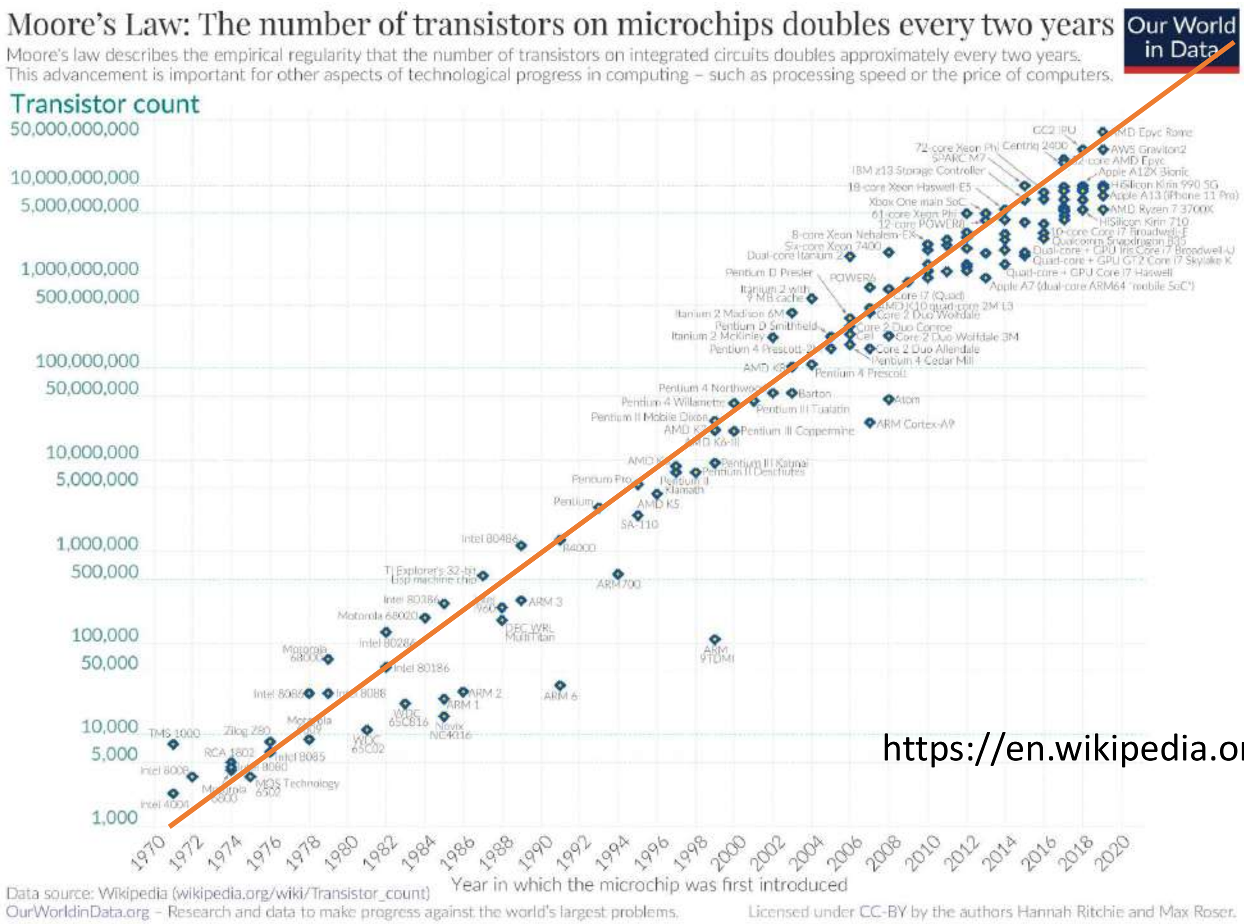
Laws fueling the information era



https://en.wikipedia.org/wiki/Moore%27s_law

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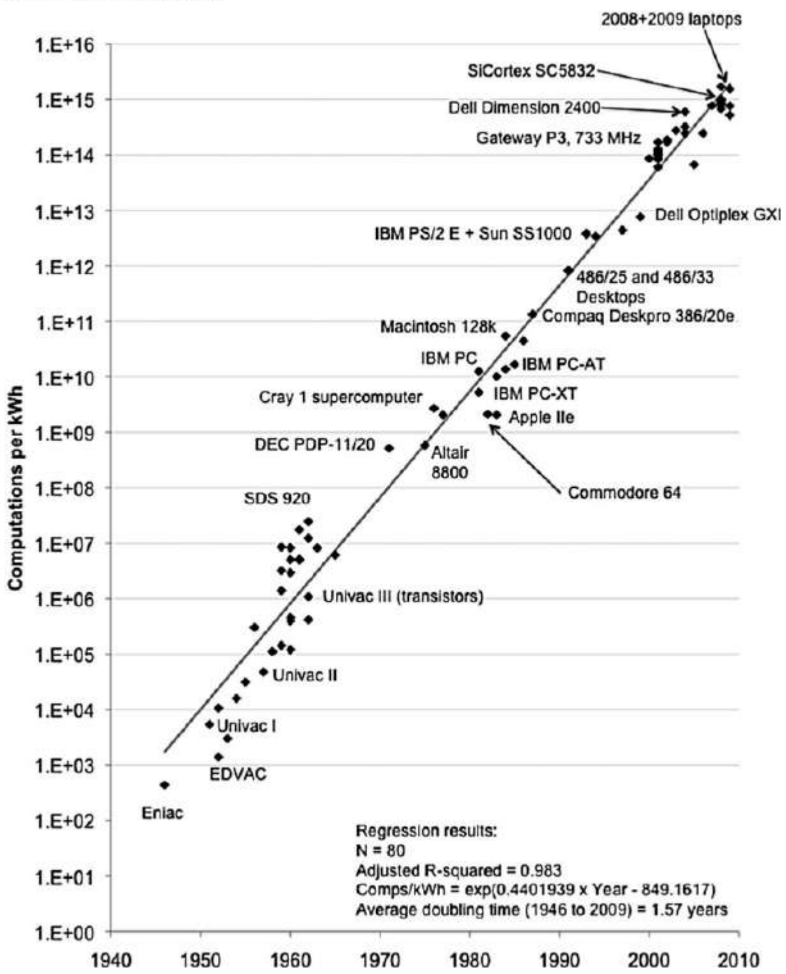
Laws fueling the information era



Largest supercomputer in the world runs on a electrical power that is equivalent to 50,000 home total electric power requirement

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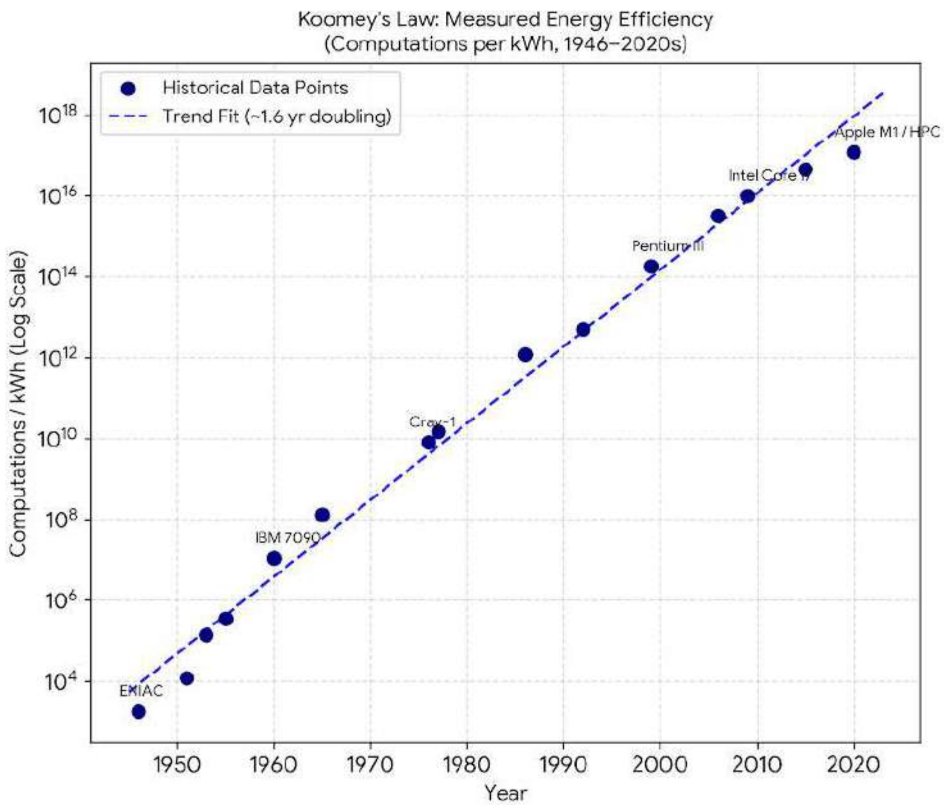
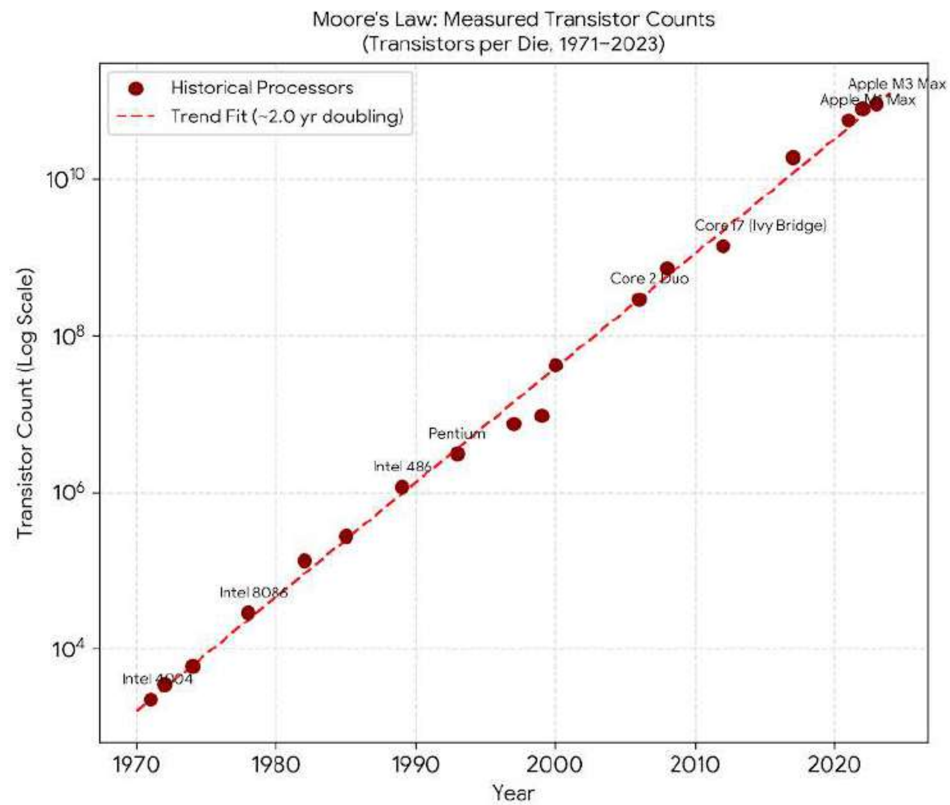
Laws fueling the information era





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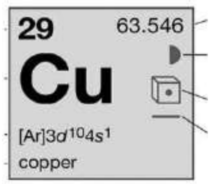
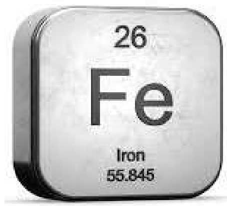
What's the next driver?



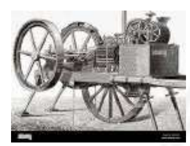
Bronze
(Cu-alloy)



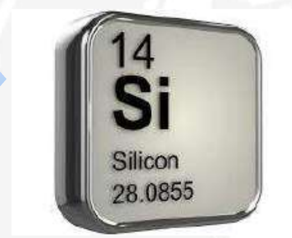
Stainless
Steel
(Fe-alloy)

Material transformation age
(1000s yrs)





Energy transformation age
(200 yrs)



Information processing age
(70 yrs)

Experience Age /
Bio-information
Age
Quantum

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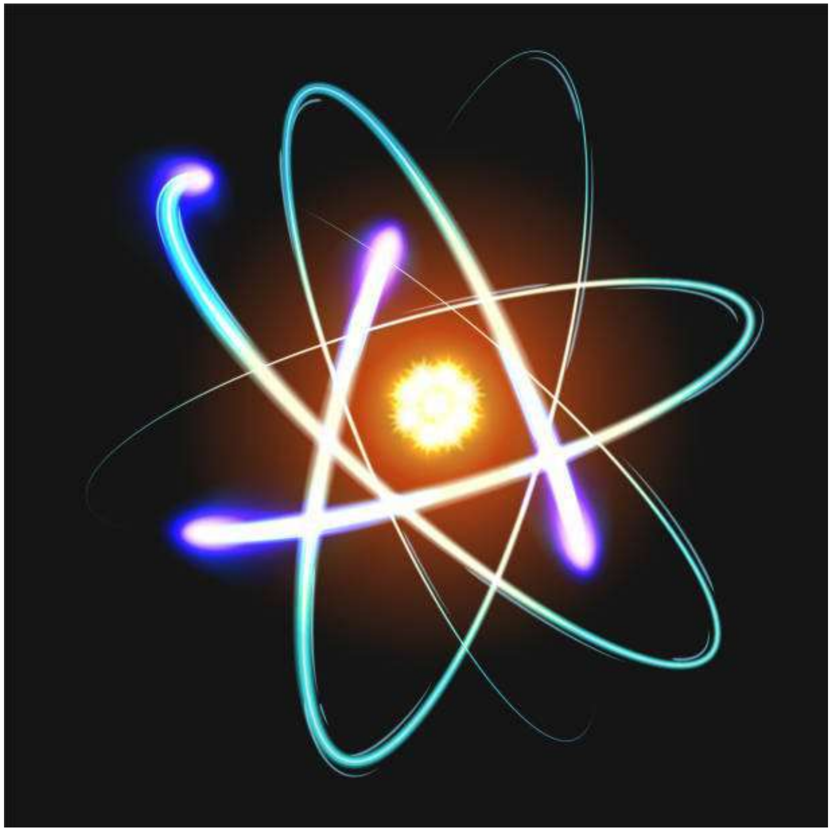
What is quantum?

Quantum mechanics



The rules that govern the world of atoms, molecules, light and other fundamental building blocks of nature

These rules are different from the rules that govern the movement of large objects

Can we harness this new fundamentally different rules for new technology

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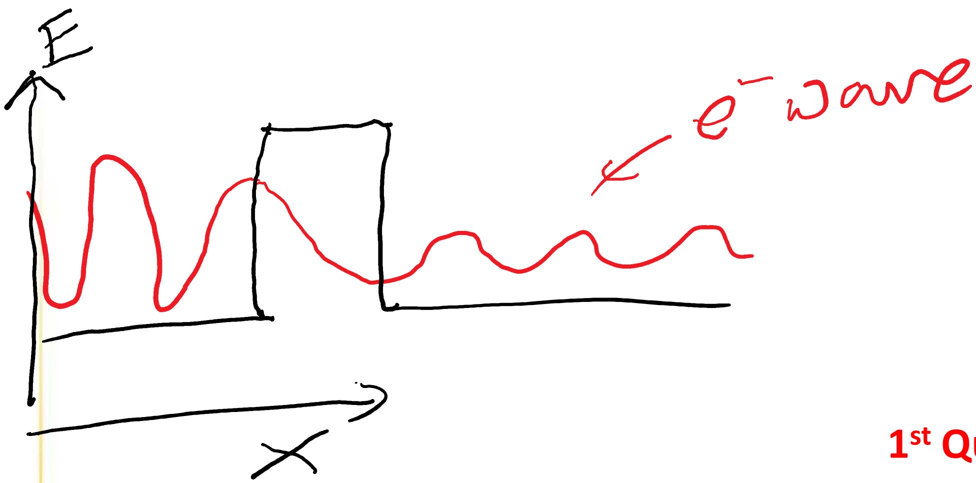
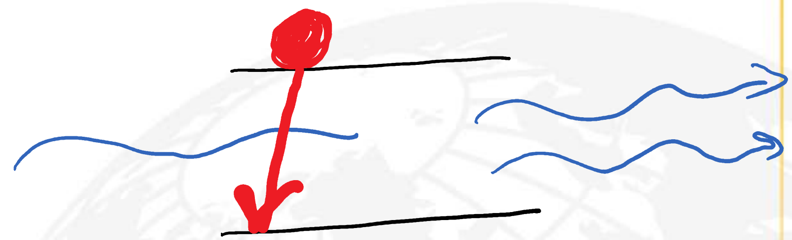
Quantum mechanics to Quantum technologies





1st Quantum revolution

Tunnelling (1980s or earlier)

- Cold emission
- Tunnel junctions
- Scanning Tunnelling Microscope
- ….

Wave particle duality

Lasing (1960s)

- Masers
- Lasers
- ….

Discreteness of energy

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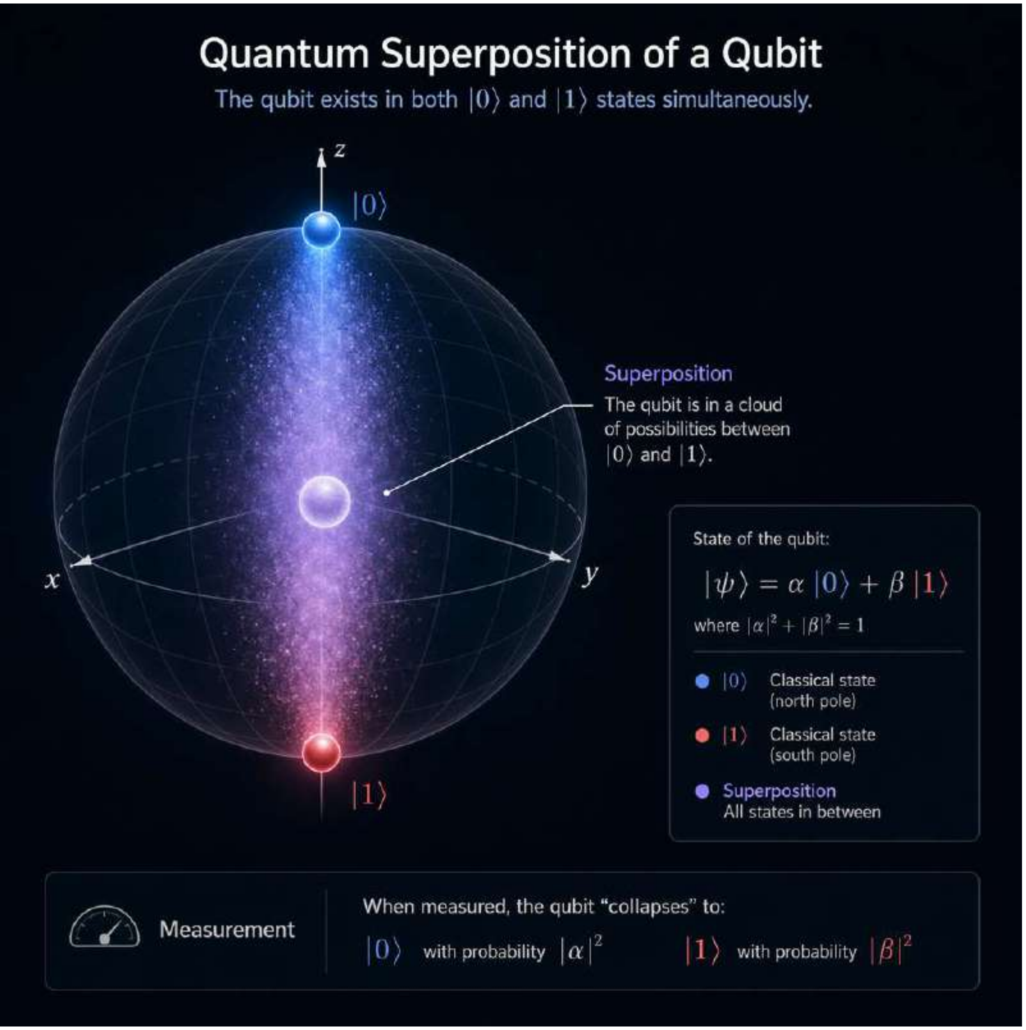
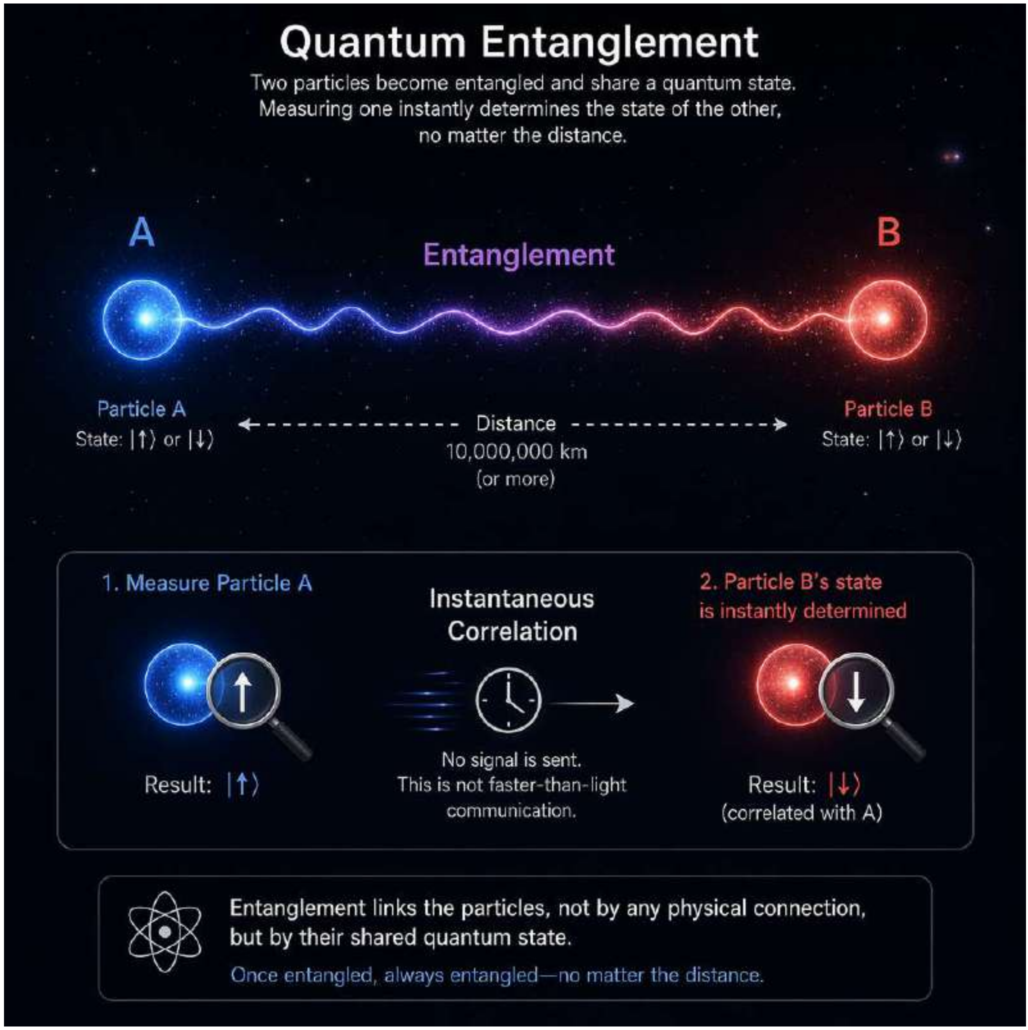
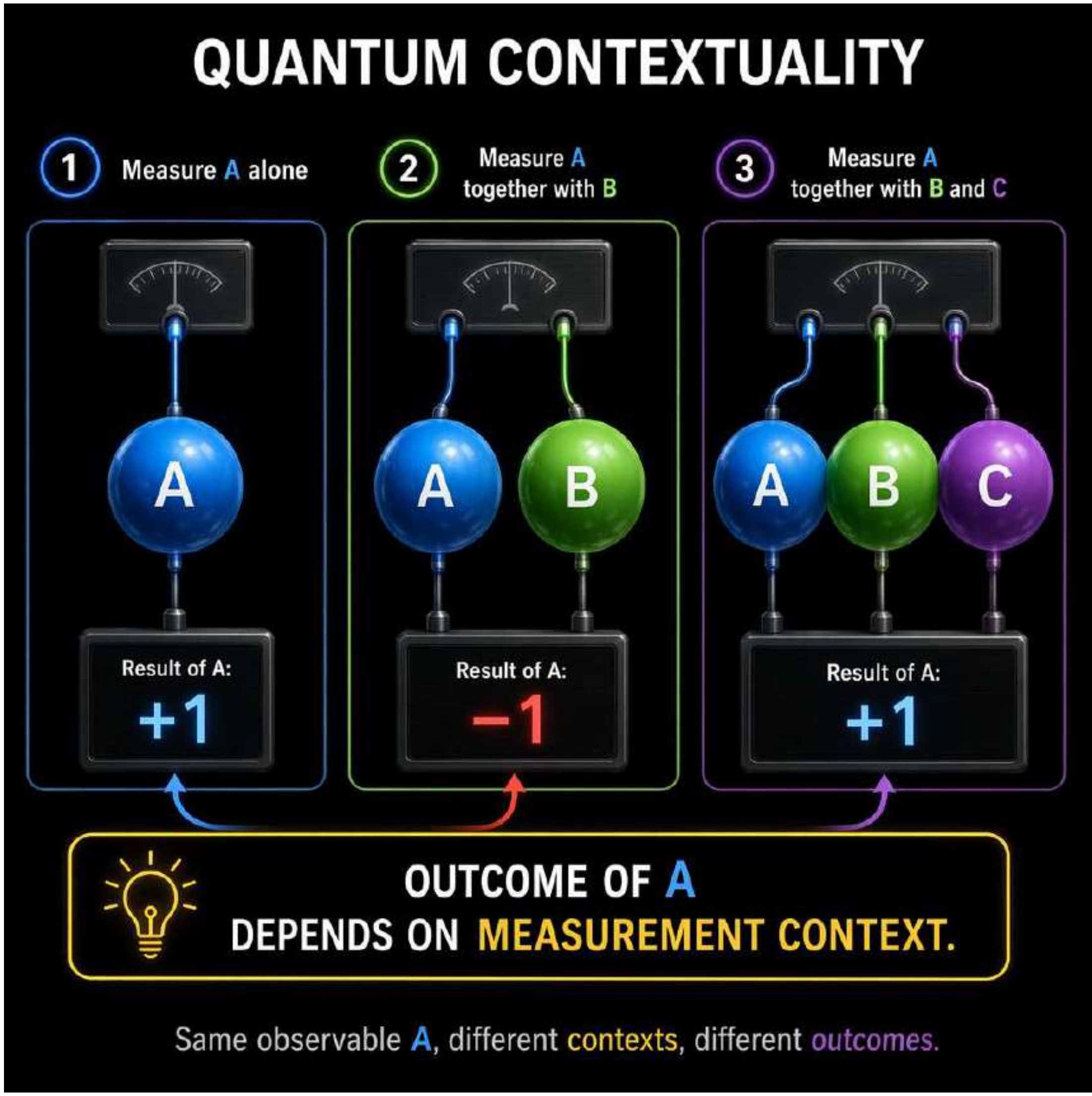
Superposition & Entanglement





Contextuality



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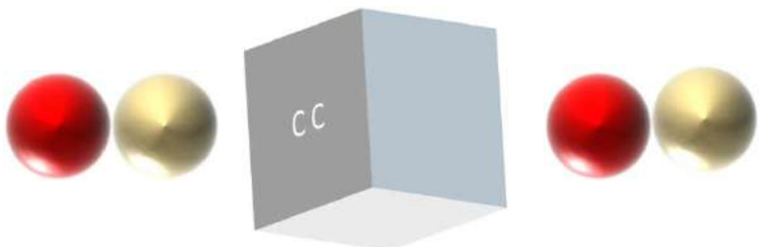
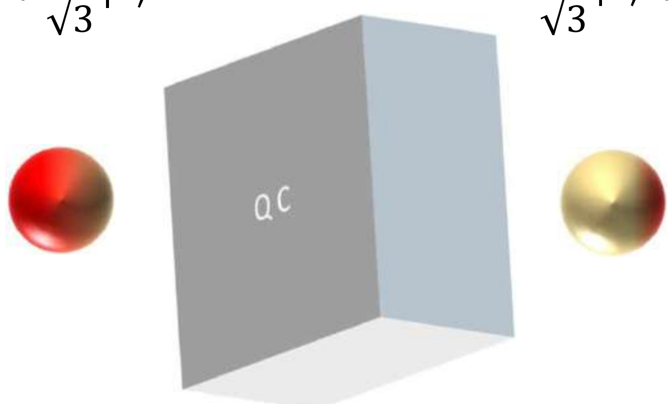
Quantum mechanics to Quantum technologies

Superposition



Minimum 2 operations

$$\frac{1}{\sqrt{3}}|0\rangle + \frac{\sqrt{2}}{\sqrt{3}}|1\rangle \qquad \frac{1}{\sqrt{3}}|1\rangle + \frac{\sqrt{2}}{\sqrt{3}}|0\rangle$$



Only 1 operation

Entanglement

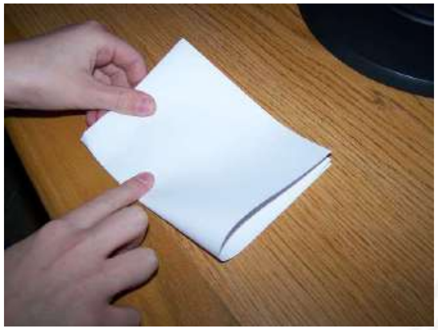
$$\frac{1}{\sqrt{3}}|1\rangle_1|0\rangle_2 + \frac{\sqrt{2}}{\sqrt{3}}|0\rangle_1|1\rangle_2$$

2nd Quantum revolution

Parallelism

Correlation

The power of true parallelism



100 micron thickness A4 paper

How many folds to reach moon?

Just 40 folds (2^{40})

Quantum mechanics to Quantum technologies

"We never experiment with just one electron or atom or small molecule. In thought experiments we sometime assume that we do, this invariably entails ridiculous consequences ….In the first place it is fair to state that we are not experimenting with single particle anymore than we can raise Ichthyosauria in the zoo" ------ 1952

"Professor Dr **Wolfgang Paul**, University of Bonn, Federal Republic of Germany and Professor **Hans G. Dehmelt**, University of Washington, USA, have introduced and developed the *ion trap technique* which has made it possible to study a single electron or a single ion with extreme precision." ------ 1989

"Serge Haroche and David J. Wineland have independently invented and eveloped methods for measuring and manipulating individual particles while preserving their quantum-mechanical nature, in ways that were previously thought unattainable." ------ 2012

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What can be we do with it?

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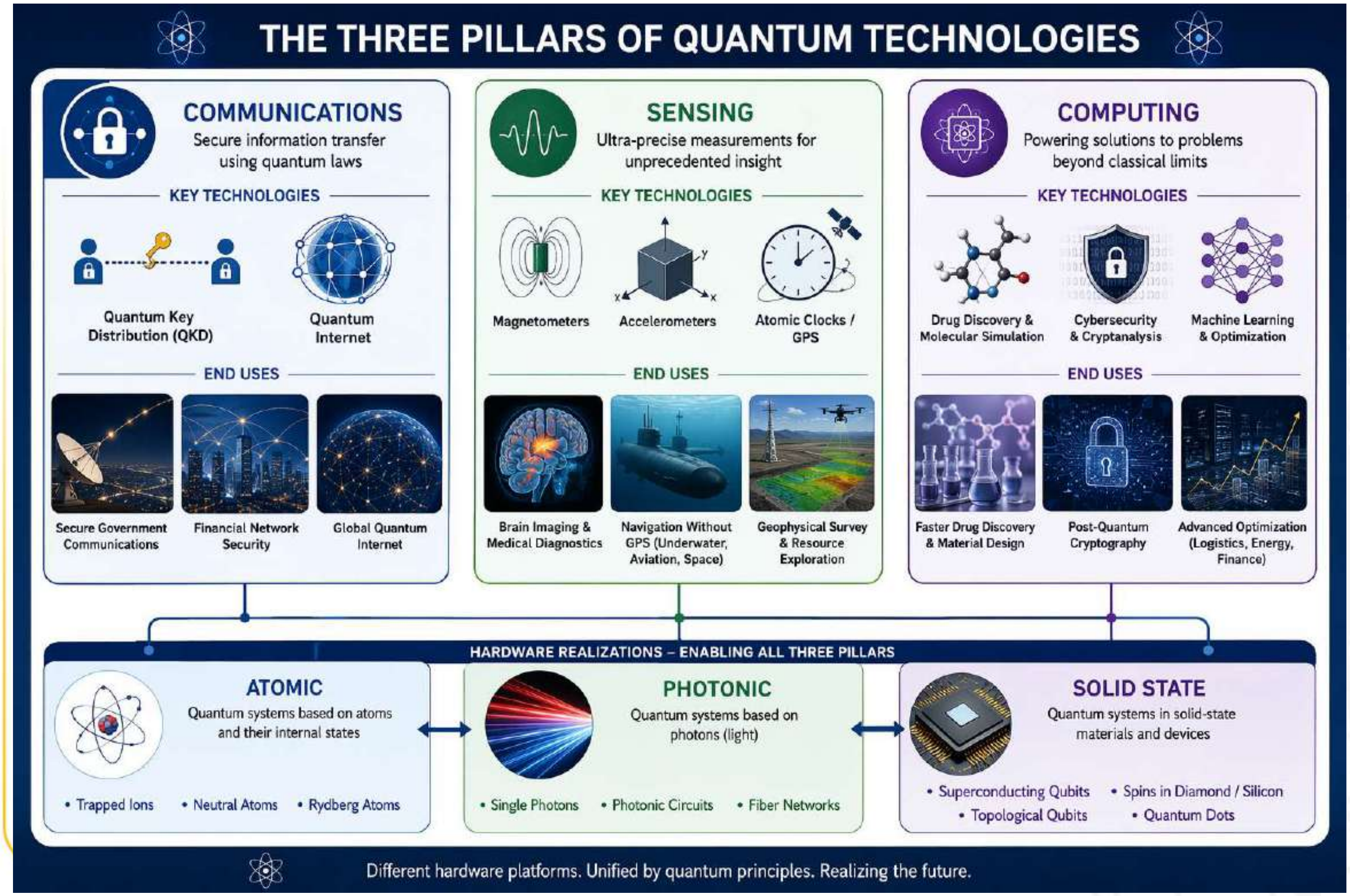
Quantum technologies



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Estimated market size

Four Quantum-Advantaged Problem Unlock 100+ Use Case at Tech Maturity

Optimization	Quantum chemistry	Machine Learning	Cryptography
Finance: Portfolio Optimization ($20-50B)	Pharma: Drug Discovery ($40-80B)	Automotive: AI Algorithms ($5-10B)	Encryption and Decryption: Government ($20-40B) Corporate ($20-40B)
Insurance: Risk Management ($10-20B)	Chemistry: Catalyst Design ($20-50B)	Finance: Anti Fraud, Trading, Risk ($30-50B)	
Logistic: Network Optimization ($50-100B)	Finance: Market Simulation ($20-35B)	Marketing: Search Optimization ($50-100B)	
Aerospace: Route Optimization ($20-50B)	Aerospace: Fluid Dynamics ($10-20B)		

Machine Learning will see application in almost all industries

Adopted from: McKinsey & Co

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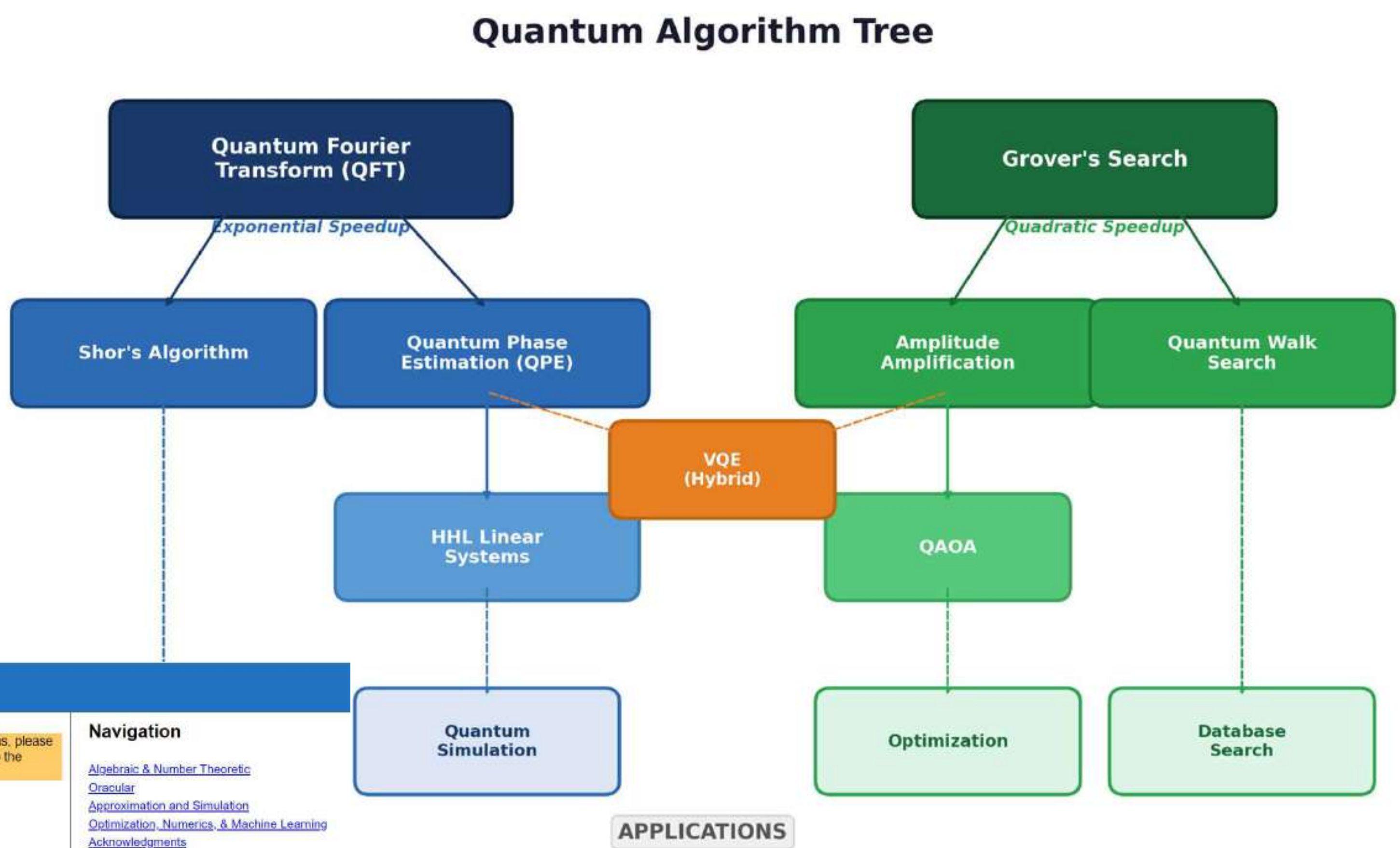
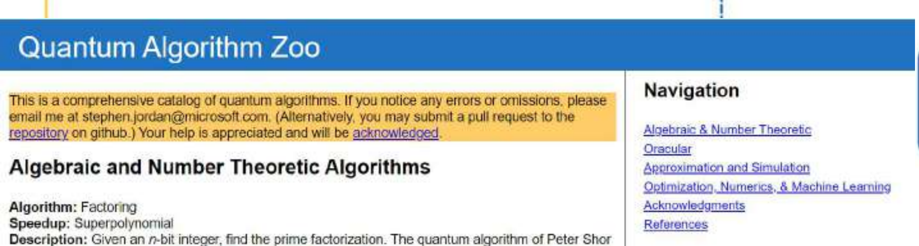
Beyond classical: unique quantum algorithms





Quantum Algorithm Zoo

This is a comprehensive catalog of quantum algorithms. If you notice any errors or omissions, please email me at stephen.jordan@microsoft.com. (Alternatively, you may submit a pull request to the repository on github.) Your help is appreciated and will be acknowledged.

Algebraic and Number Theoretic Algorithms

Algorithm: Factoring
Speedup: Superpolynomial
Description: Given an *n*-bit integer, find the prime factorization. The quantum algorithm of Peter Shor

Navigation

- Algebraic & Number Theoretic
- Oracular
- Approximation and Simulation
- Optimization, Numerics, & Machine Learning
- Acknowledgments
- References

https://quantumalgorithmzoo.org/

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Status of hardware

5Mb Hard drive 1956

ENIAC (IBM) 1945

IBM Q experience (IBM) 2026

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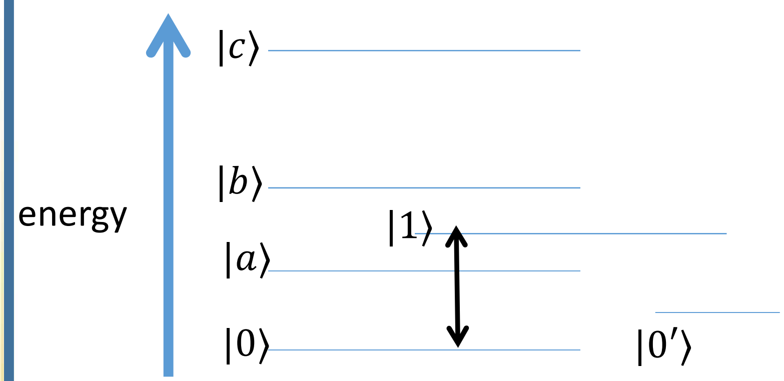
Introduction to qubits

Qubit



1. Initialization.
2. Long lifetime.
3. State manipulation.
4. Unique measurement.
5. Scalable.

Physical qubit	**Platforms**
Atoms	Ion trap Atom tweezers
Optical Photons	Photonic integrated circuits
Microwave Photons	Superconducting circuits Si-donor

State-of-the-art performance (SOTA)

Status as of August 2026

Present state-of-the-art comparison

Parameter	Superconducting	Ion trap	Photonics	Silicon based	Topological (notional)	NMR (pioneer)
Qubit lifetime	~50-100 μs	~ 1000s	~150 ms	~1-10 s	100 s	100 – 4000 ms
# qubits demonstrated	~ 20-400	~20-100	~3×6	~2-7	1 target	10
Gate fidelity/error	99.%	99.99%	98%	90%	99.9999%	98%
Operation time	~10-50 ns	~3-10 ms	~1 ns	~1-10 ns	NA	10 ms
Connectivity	Partial	Fully	Partial	Partial	-	-
scalability	75%	50%	25%	25%	NA	5%
TRL	5	4	3	3	1	NA

Disclaimer: Not complete or up-to-date

Comparative Performance Matrix

Physical SOTA Metrics Across All Four Modalities (2024–2026)

Modality	SOTA Physical Qubits	2-Qubit Gate Fidelity	Coherence Time	SOTA Logical Qubits	Primary Bottleneck
Superconducting (IBM/Google)	120 (IBM Nighthawk)	~99.9%	100–300 µs	1 (Google Willow)	Crosstalk & cryogenic cooling
Trapped Ion (Quantinuum/IonQ)	56 (Quantinuum H2-1) 98 (Helios)	99.9% – 99.99%	Seconds–Minutes	48 (Quantinuum)	Slow gates, scaling ion chains
Neutral Atom (QuEra/Atom Comp.)	1,180+ (Atom Computing)	~99.5% – 99.73%	Seconds	96 (QuEra/Harvard)	Atom loss & shuttling latency
Silicon Spin (Diraq/Intel)	~12 (Diraq/Intel)	~99%	Milliseconds	Early demos (2026)	Fabrication variability

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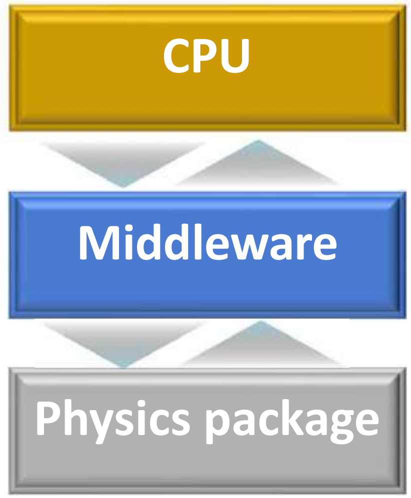
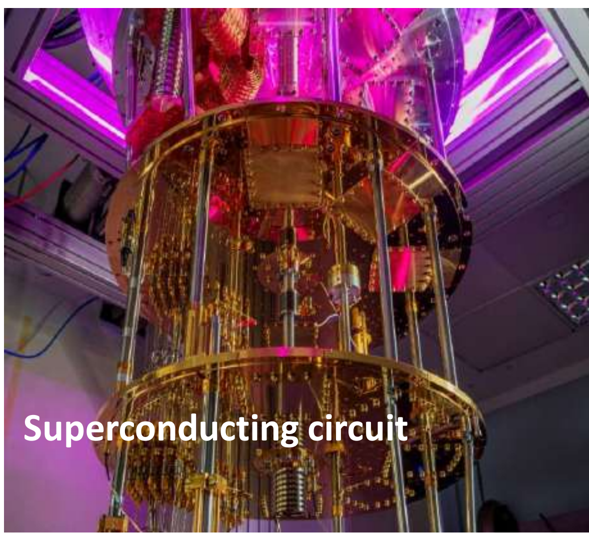
Quantum computing systems

Solid state vs ion trap



Technology stacks

1. Dilution refrigerator
2. Microwave engineering
3. Cryogenic cabling
4. Superconducting circuit



Technology stacks

1. Vacuum Technology
2. RF technology
3. Optical technology
4. Cryogenic
5. Trapology

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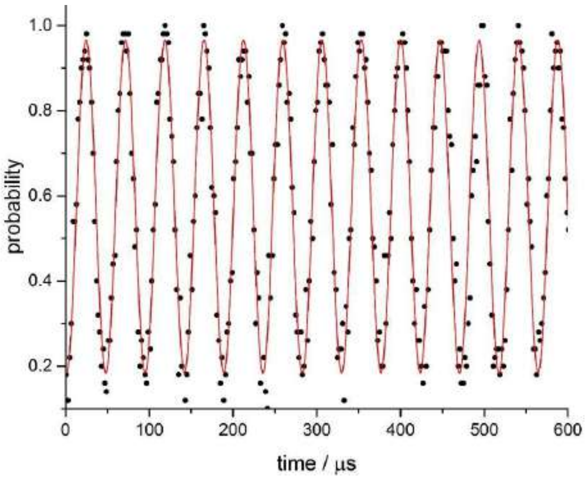
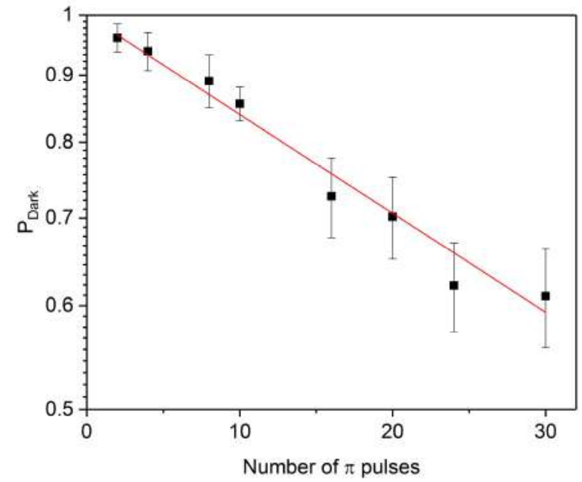
System performance

Gate level benchmark





Heating rate: ~ 20/ sec

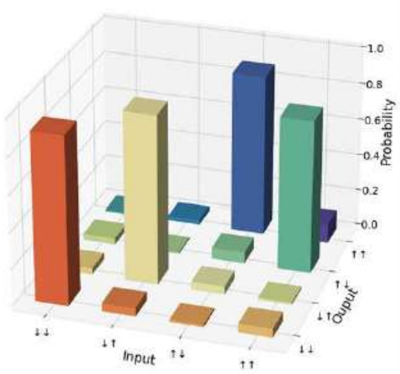
T2: over 3 ms

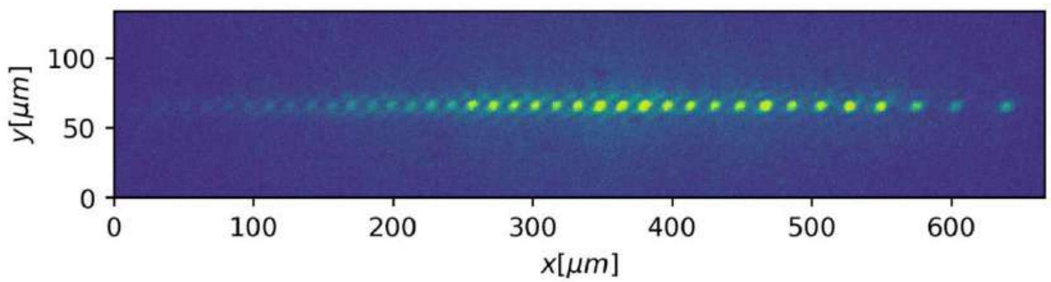
T1: 30 s

Gate operation times:

2-5 μs (single)

~ 1ms (2-qubit)





Fidelity:

99.95% (Single)

95% (2-qubit)

Stable trapping of over 30 ions having minimum inter-ion distance of 15 μm

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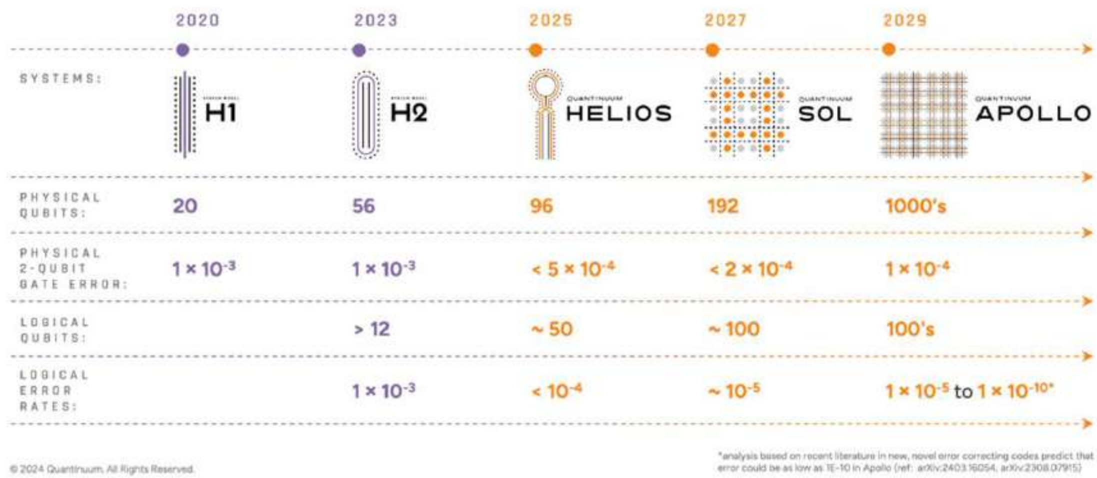
Significant Roadmaps

IonQ

- Updated in Jan 2026 after a series of takeovers including Oxford Ionics
- They are consistently achieving proposed targets thus far

Quantinuum

- Updated in 2025
- Has been consistent in their deliverables



Application example

Adversarial attack in machine learning

Quantum computing risk matrix

An estimate

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Assessment of risk

RISK MATRIX: FINANCIAL INSTITUTIONS DUE TO OPERATIONAL QUANTUM COMPUTERS

RISK AREA	LIKELIHOOD			IMPACT		
	LOW	MEDIUM	HIGH	MEDIUM	HIGH	VERY HIGH
Public-key encryption failure	LOW	MEDIUM	HIGH	HIGH	CRITICAL	CRITICAL
'Harvest now, decrypt later' attacks	MEDIUM	HIGH	CRITICAL	HIGH	CRITICAL	CRITICAL
Payment system disruption	MEDIUM	HIGH	CRITICAL	HIGH	CRITICAL	CRITICAL
Vendor and third-party exposure	LOW	MEDIUM	HIGH	HIGH	CRITICAL	CRITICAL
Regulatory and compliance risk	LOW	MEDIUM	HIGH	HIGH	HIGH	CRITICAL
Digital identity/ IAM compromise	LOW	HIGH	CRITICAL	HIGH	CRITICAL	CRITICAL
Market/trading model disruption	LOW	MEDIUM	HIGH	HIGH	CRITICAL	CRITICAL
Reputational damage	LOW	MEDIUM	HIGH	HIGH	HIGH	CRITICAL
Operational migration failure	LOW	MEDIUM	HIGH	HIGH	HIGH	CRITICAL

LOW: Manage with routine controls
MEDIUM: Monitor and mitigate
HIGH: Act and mitigate urgently
CRITICAL: Immediate action required

Choice is between

"Ignorance is bliss" vs "knowledge is power"

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