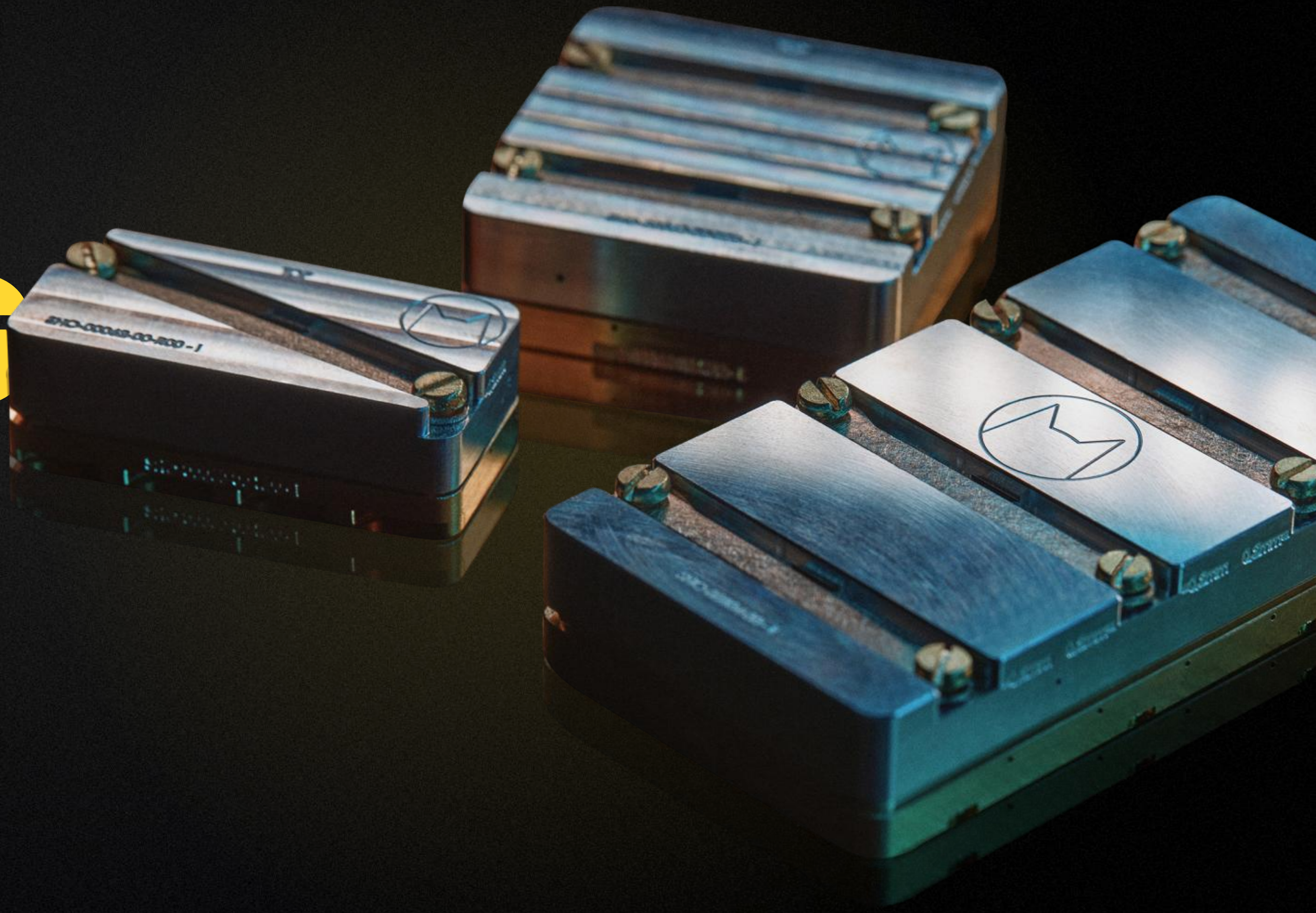
THE PATH TO A NEW **COMPUTING ERA**



HPC User forum

Rémi de La Vieuville

OCTOBER 2025

ALICE & BOB
READY FOR THE NEXT CHAPTER

Théau Peronnin
CO-FOUNDER & CEO

Raphaël Lescanne
CO-FOUNDER & CTO

2020
Founding date

140+
People: 45+ PhDs, 100+ R&D

2
Offices: Paris & Boston

€130m
Raised to date

Each cat qubit
Already equivalent to 33 Google physical qubits

7 minutes
Bit-flip time of a single cat qubit (vs. c.1ms for others)

44
Core patents on cat qubits

140
Mentions of Alice & Bob's Tech by AWS

Up to €150m
Public procurement plans
– PROQCIMA + DARPA

Cloud Access
Signed with major providers

"The Box"
To build commercial relationships

10+
"The Box" clients in pipeline

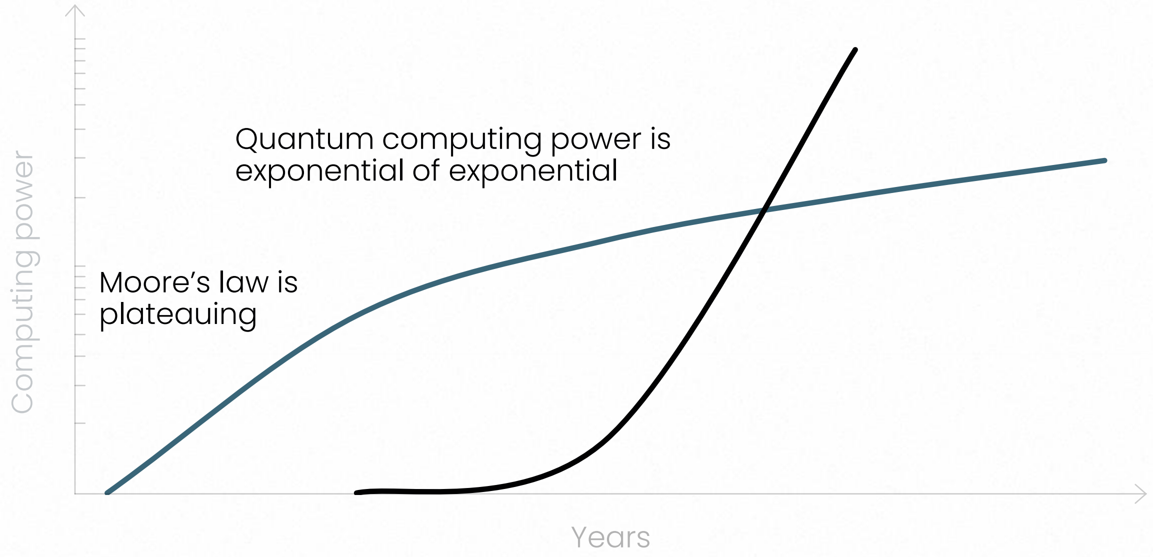
Forget about quantum: the goal is exponential increase in computing power to create value

Quantum is the engine of the next economic breakthrough

→ Source

1. McKinsey

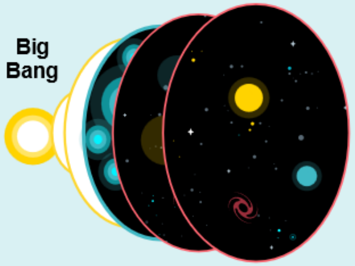
Quantum computing is the only way to generate exponential increase in computing power



+1 qubit = **x2** computing power

Quantum Computers Expand the Set of Problems we can Solve, Unlocking a Technological Revolution

			Today's RSA encryption
Key to decrypt (bits)	512 → x2 →	1024 → x2 →	2048
CLASSICAL COMPUTER HP Frontier Supercomputer	**0.5 Milliseconds** (20x faster than a hummingbird flaps its wings)	**3 Months**	**6 Trillion years** (400x The age of the universe)
QUANTUM COMPUTER[1] Alice & Bob's Architecture	**10 Hours**	**1 Day**	**1 Week**



- **Life Sciences**
- **Chemicals**
- **Energy**
- **Telecom**
- **Manufacturing**
- **Logistics**
- **Finance**

$850 billion[2]

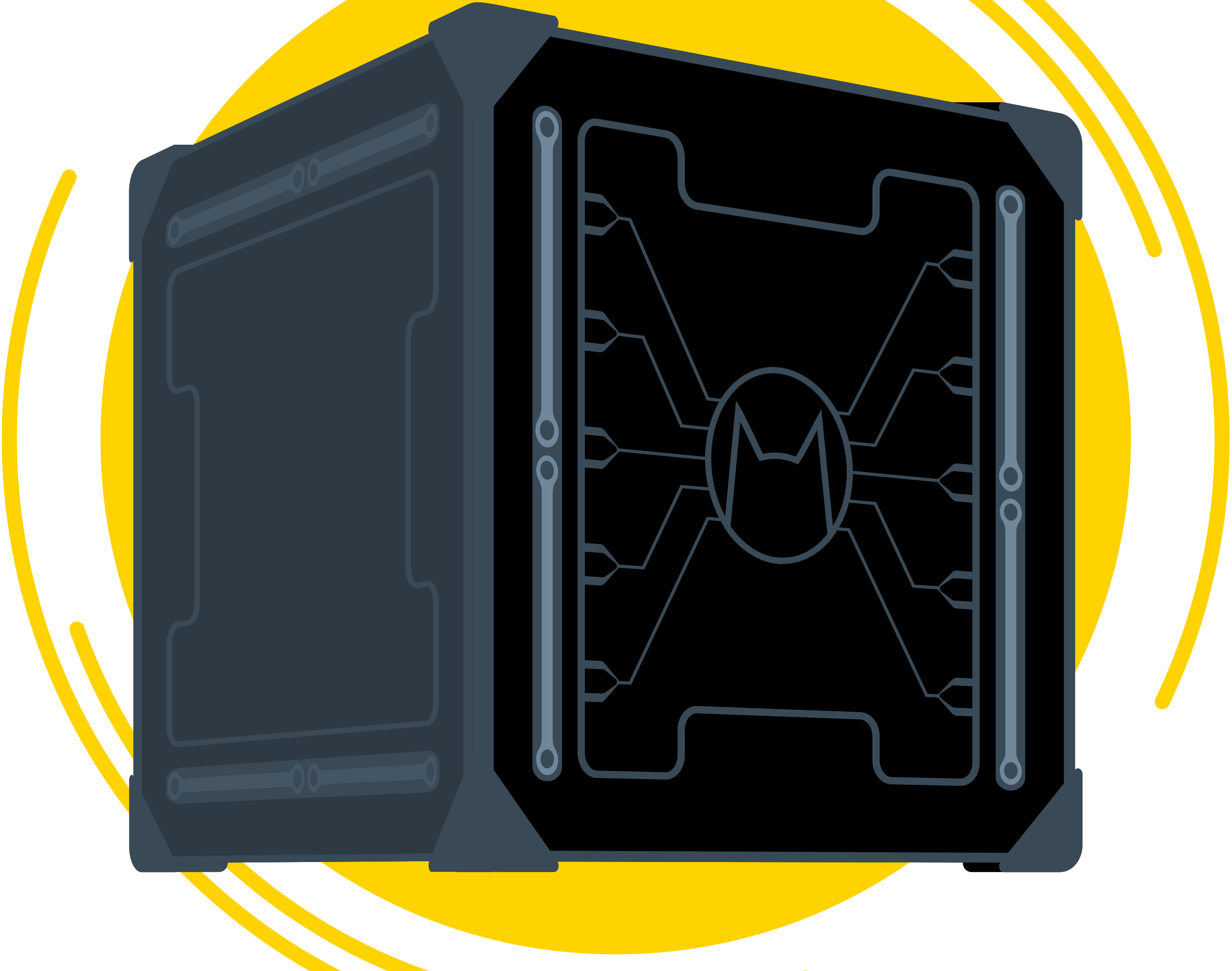
1. *Élie G. et al."Performance Analysis of a Repetition Cat Code Architecture" Physical Review Letters 131, no. 4 (2023).*
2. *Boston Consulting Group, 2024*

Disruption of computing capacities have led to the greatest economic impacts

The quantum era will see the emergence of new tech leaders

	1960	1980	2000	2010	2030
Technological revolution	MAINFRAME	PC	DATA NETWORKS	AI	QUANTUM
Disruptive players	IBM	intel	Google, aws, SAMSUNG	NVIDIA, AMD, arm	......

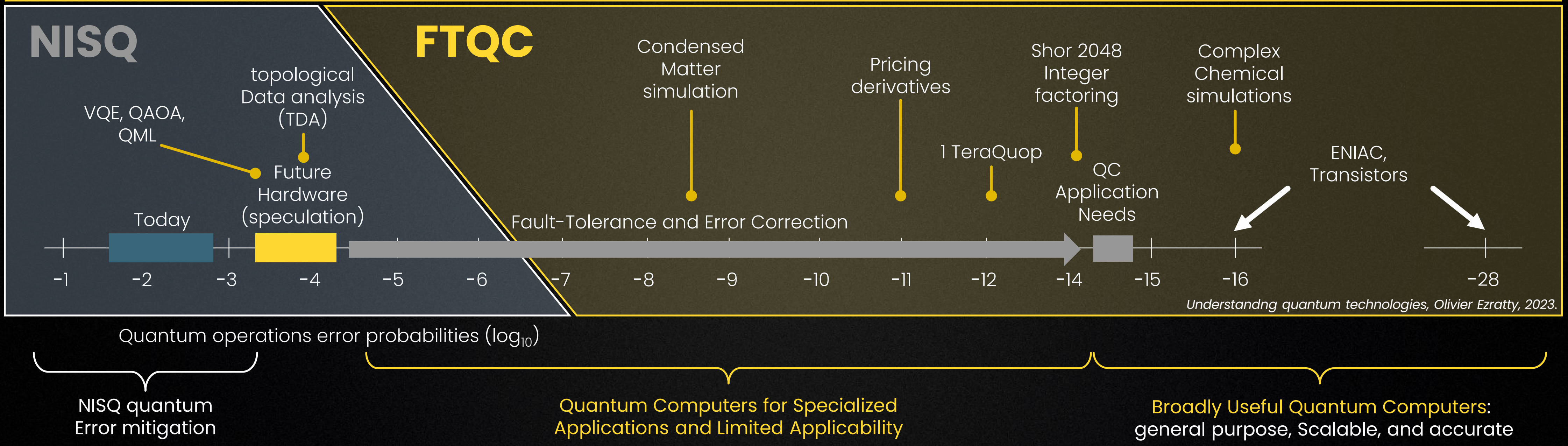
The Paradox of Quantum Computing



Quantum computers are still not reliable enough for their first use case

Very low error rates is required to unlock exponential speed-up

QC are not reliable enough at the moment



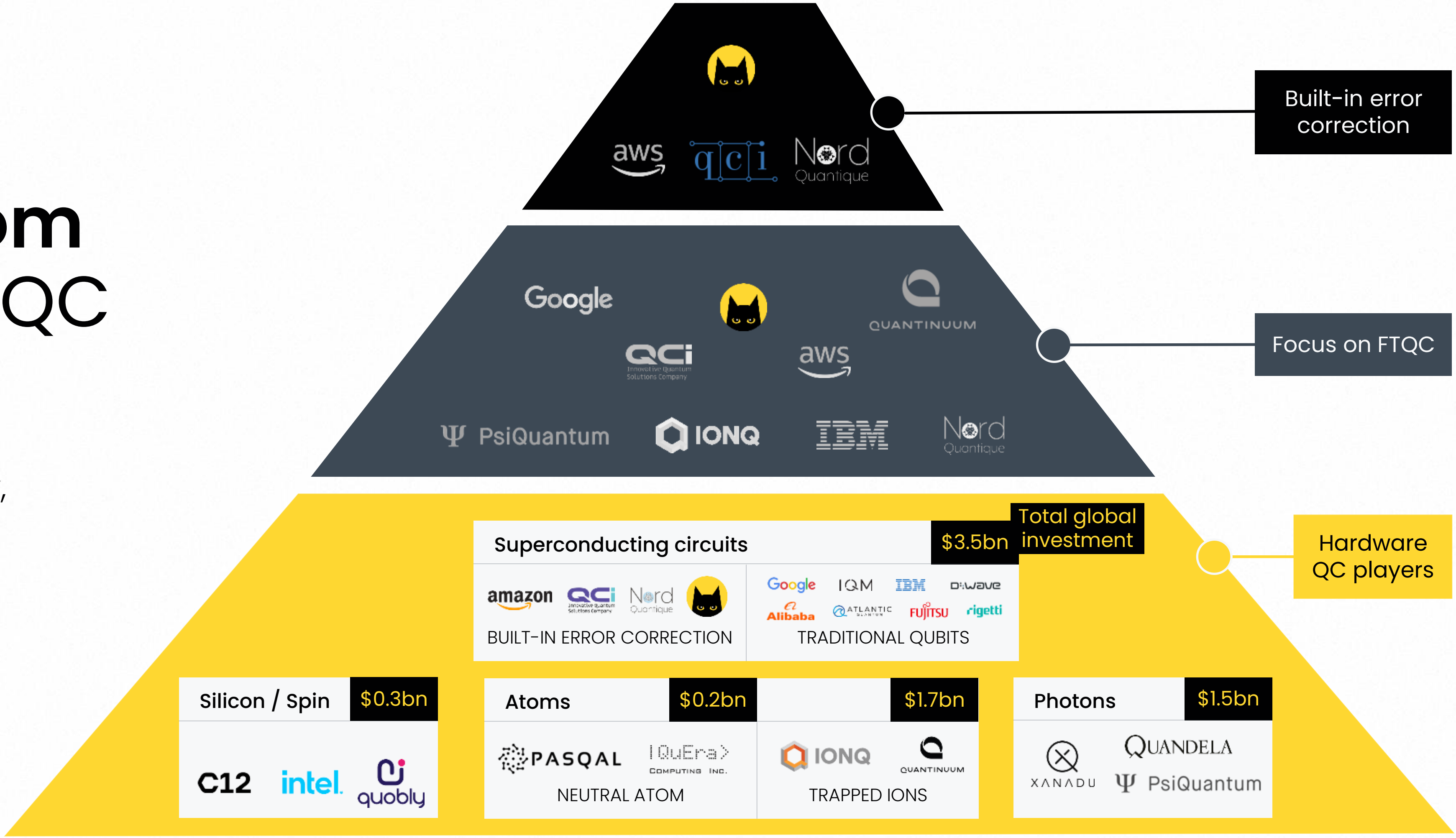
	Chemistry	Finance	Cryptography
# of perfect qb	100 - 1,000	10,000	1,000 – 10,000
# of gates	10^{14} - 10^{16}	10^{10} - 10^{11}	10^{11}
Error per gate	10^{-17}	10^{-13}	10^{-14}

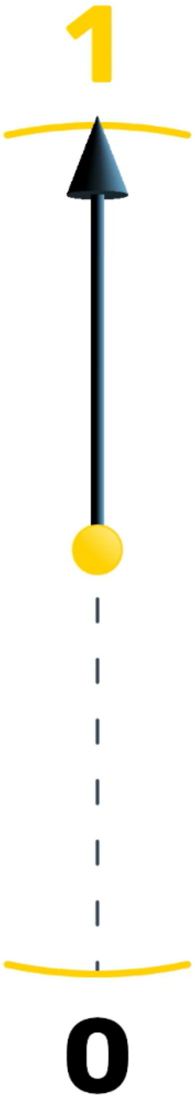
How Alice & Bob differentiates **from other hardware** QC actors

A superconductor-based technology, aiming at FTQC with our built-in error corrected qubit: the cat qubit

12x

Increase in cat qubit research publications over the past 5 years

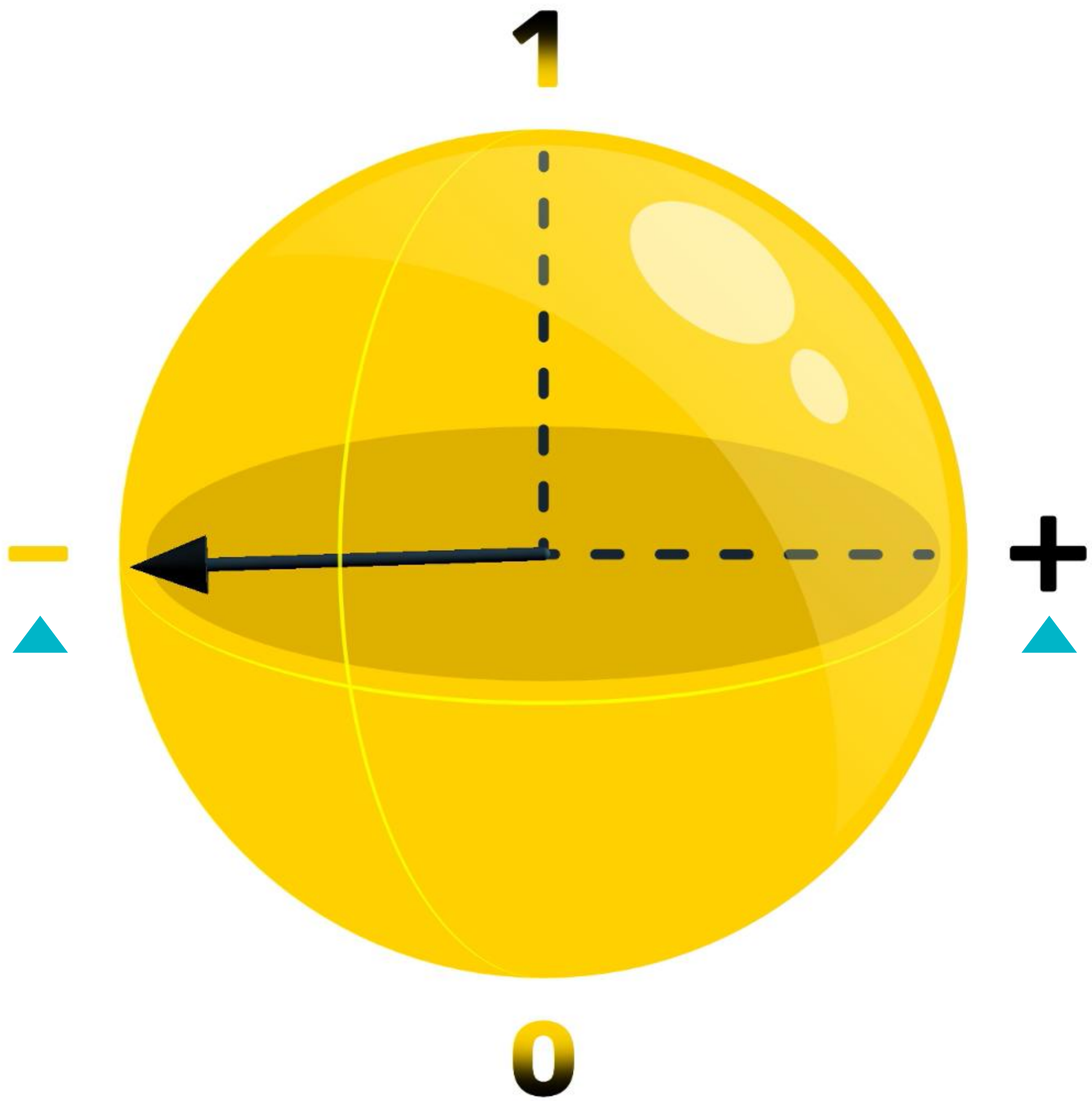



1
0

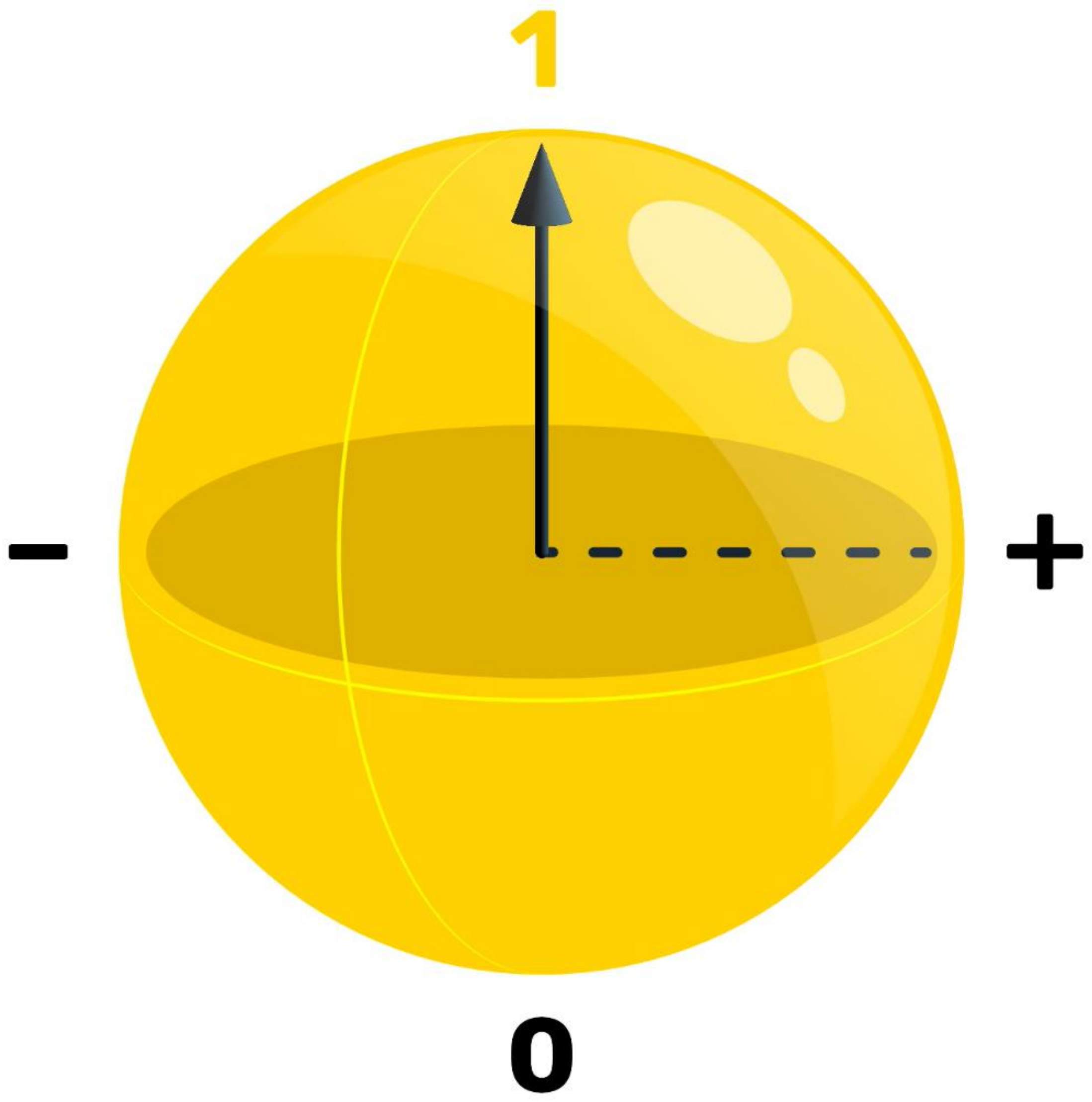
Bit

Bit

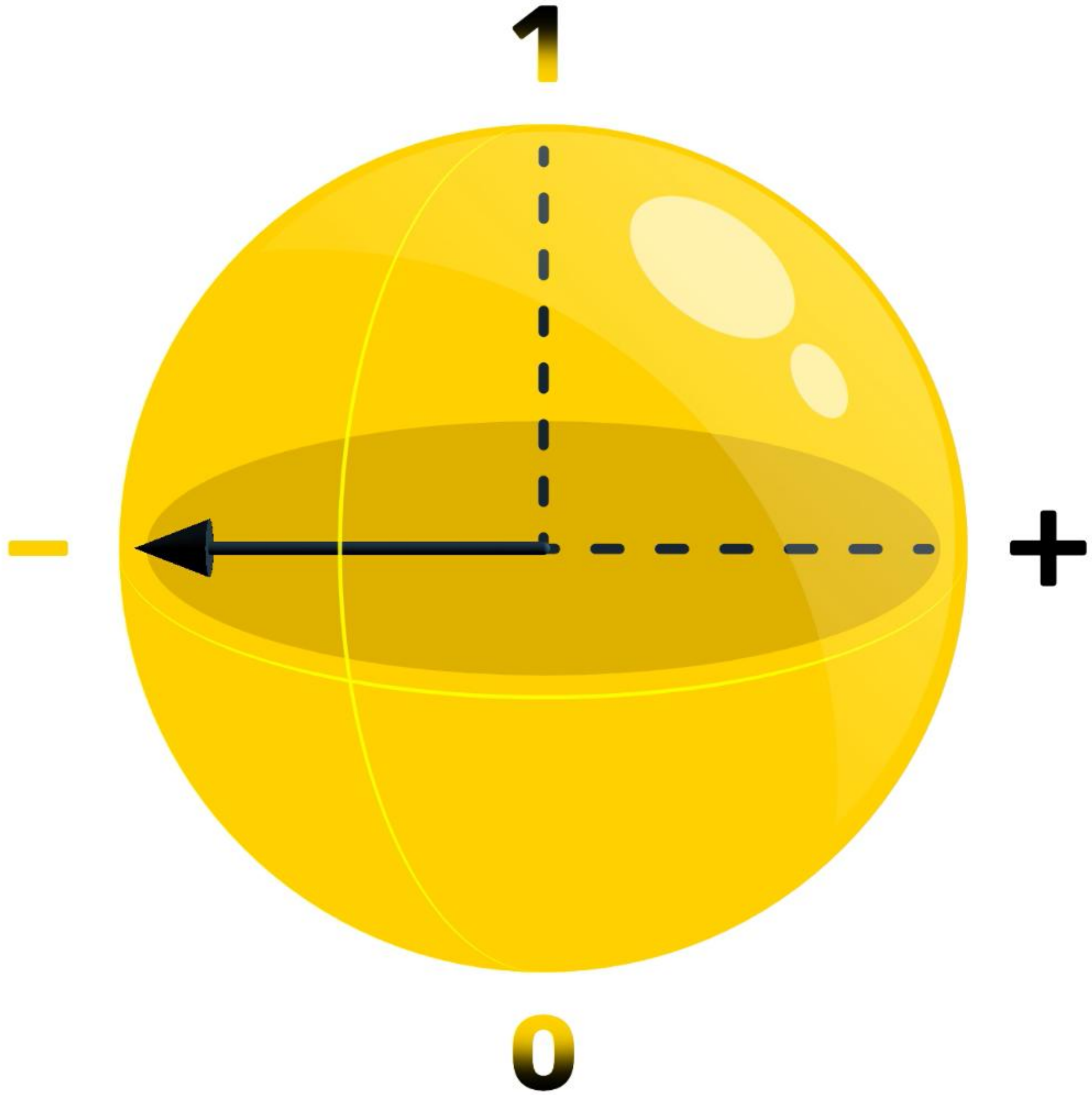
Phase

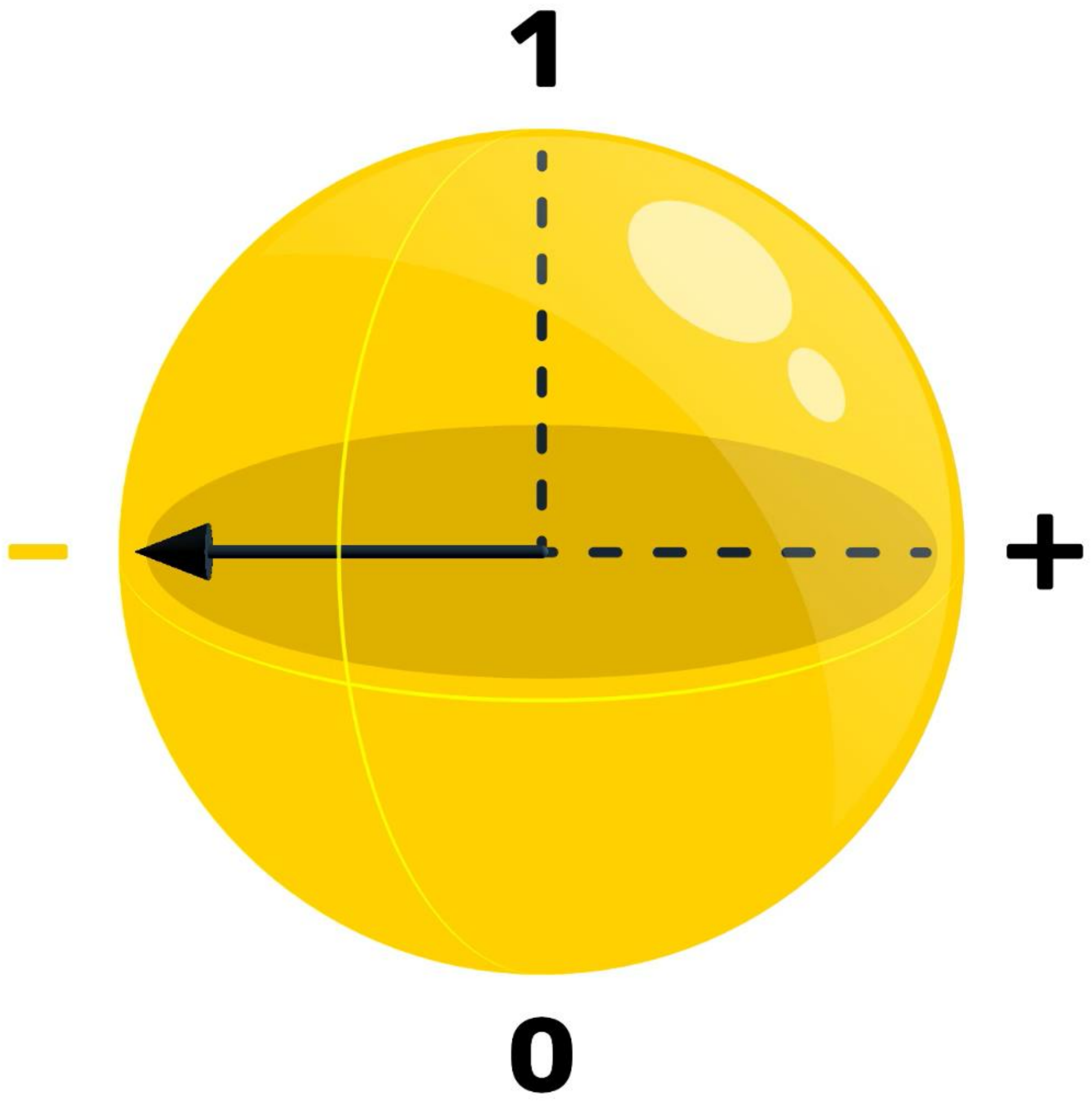


Bit-Flip



Phase-Flip




1
–
+
0

“Redundant” Error Correction is The best Solution to Date to Escape the Paradox

QUANTUM ERROR CORRECTION

(In simple words)

// .01

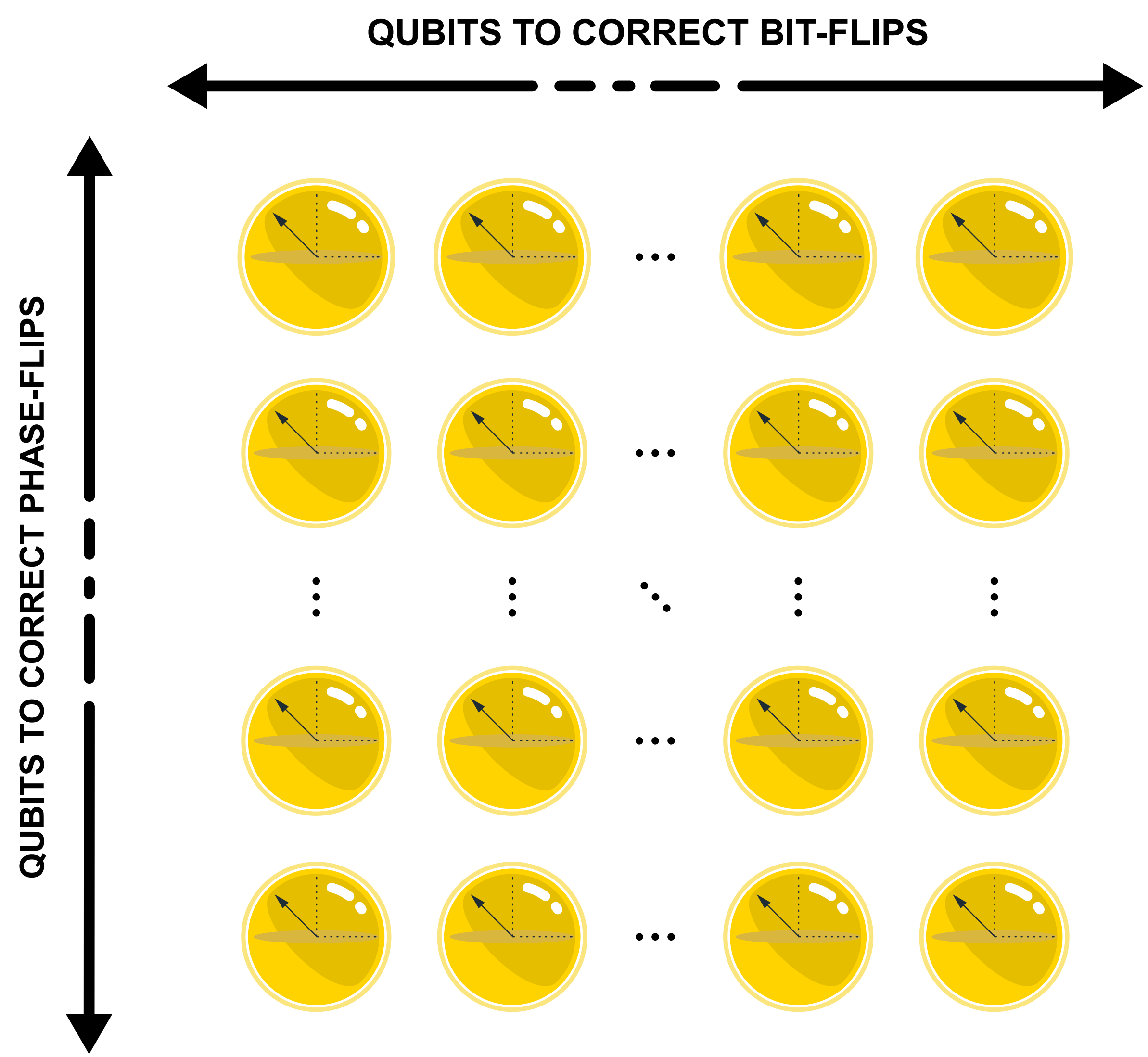
Same information within a **set** of **qubits**

// .02

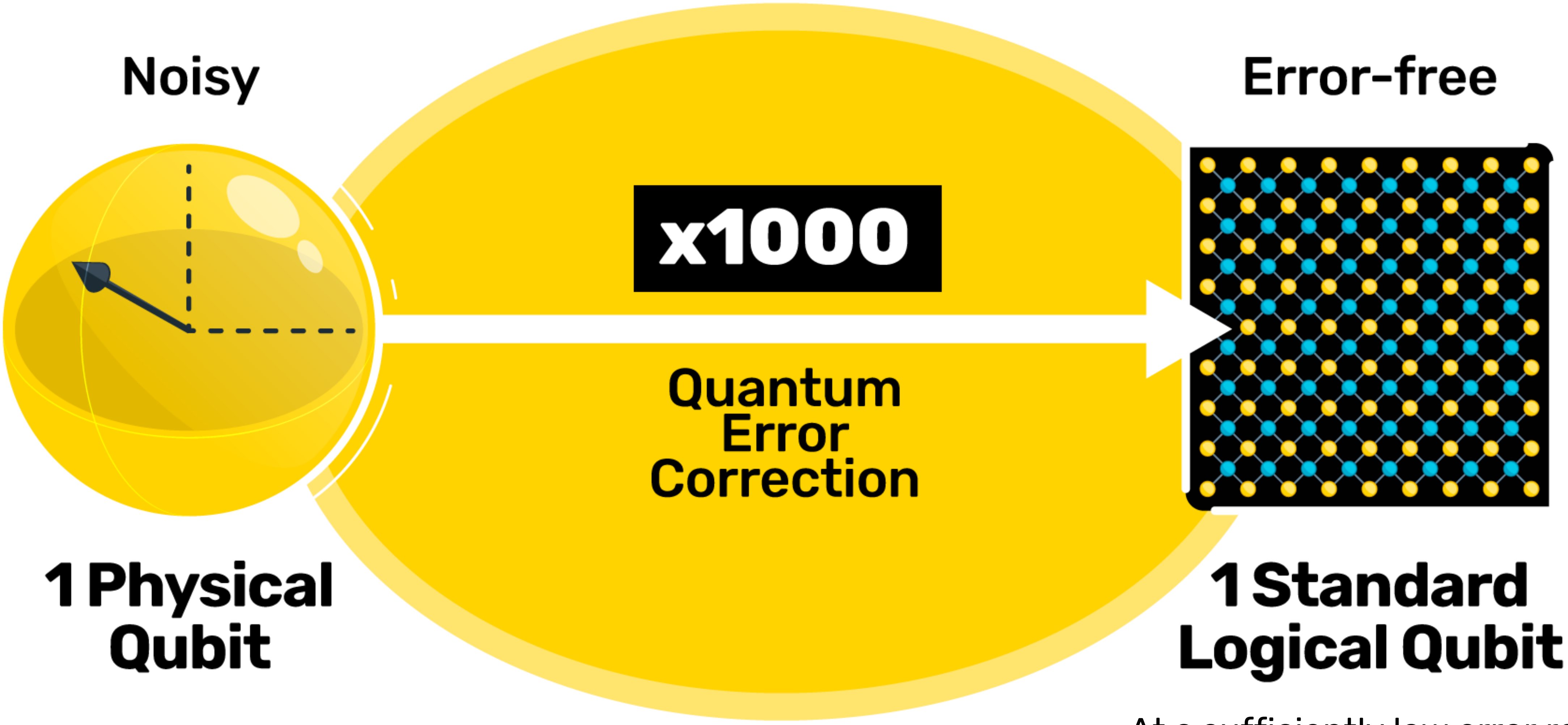
Check if the qubits in the set “**agree**” with each other

// .03

If a **qubit is different** from its neighbors, **correct it**



Quantum error correction is qubit-expensive…

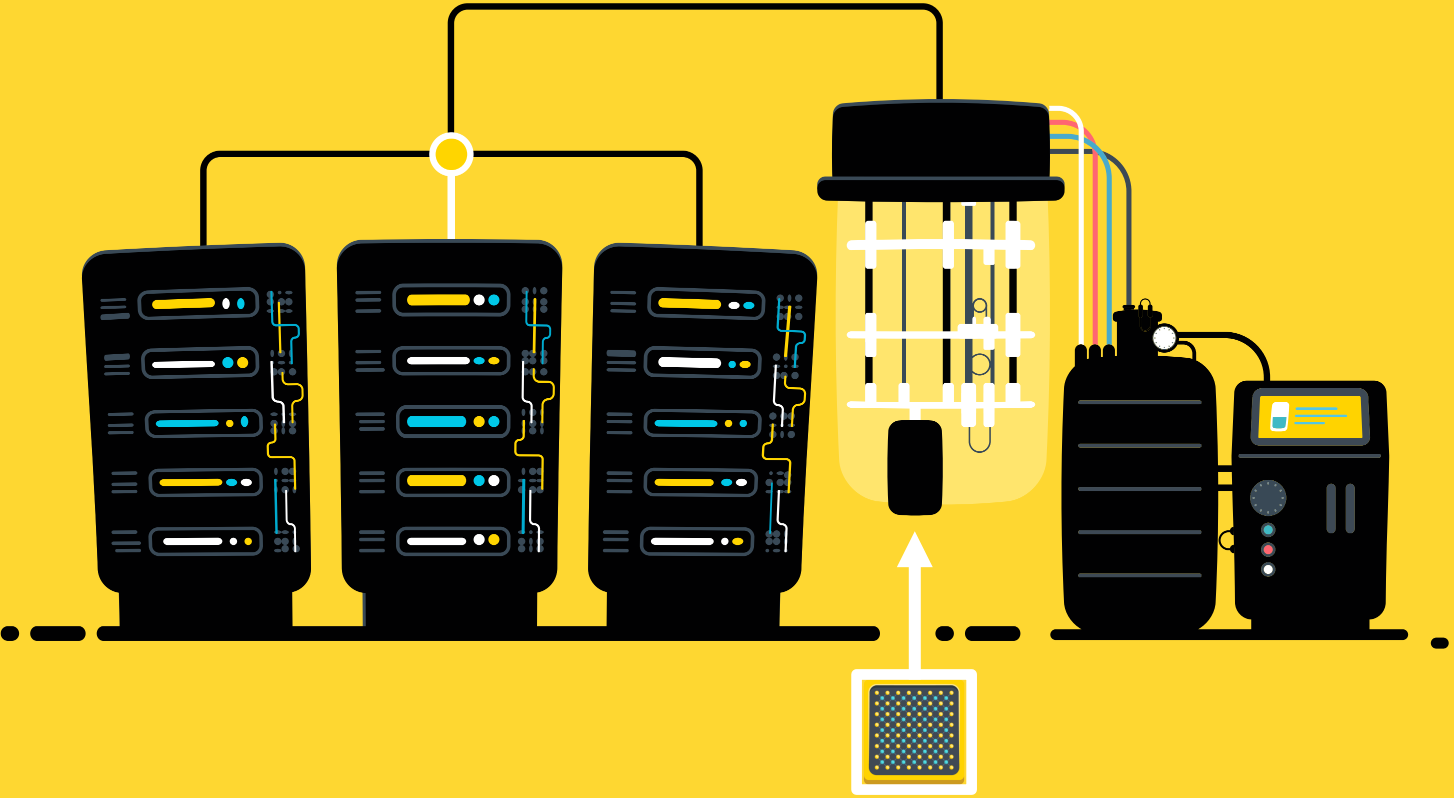


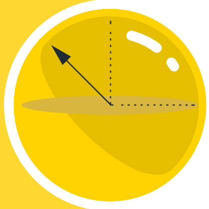
At a sufficiently low error rate to decrypt RSA 2048 [1,2]

1. *Craig G. et al. "How to Factor 2048 Bit RSA Integers in 8 Hours Using 20 Million Noisy Qubits." Quantum 5 (2021)*
2. *Rajiv A., et al. "Quantum Error Correction Below the Surface Code Threshold." (2024)*

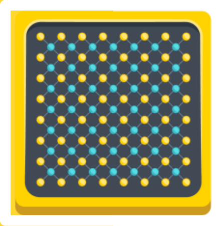
With Today’s Technology You Would Need A Full Cryogenic System And 3 Dense Control Racks To run a Logical Qubit

~10 M$ | ~50 kW





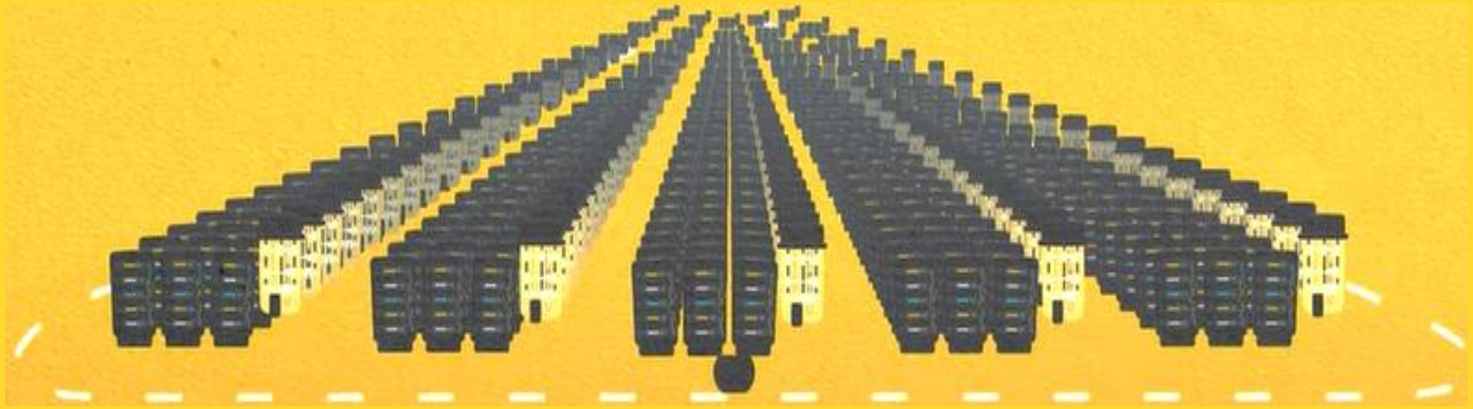
1 000
Physical Qubits

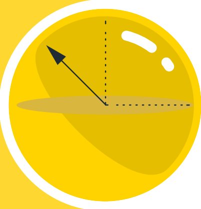


1
Logical Qubit

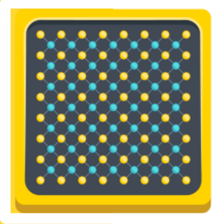
What Does it Mean for Quantum Computing at Scale?

100 CRYOSTATS → **1 B$** **1 000 kW**



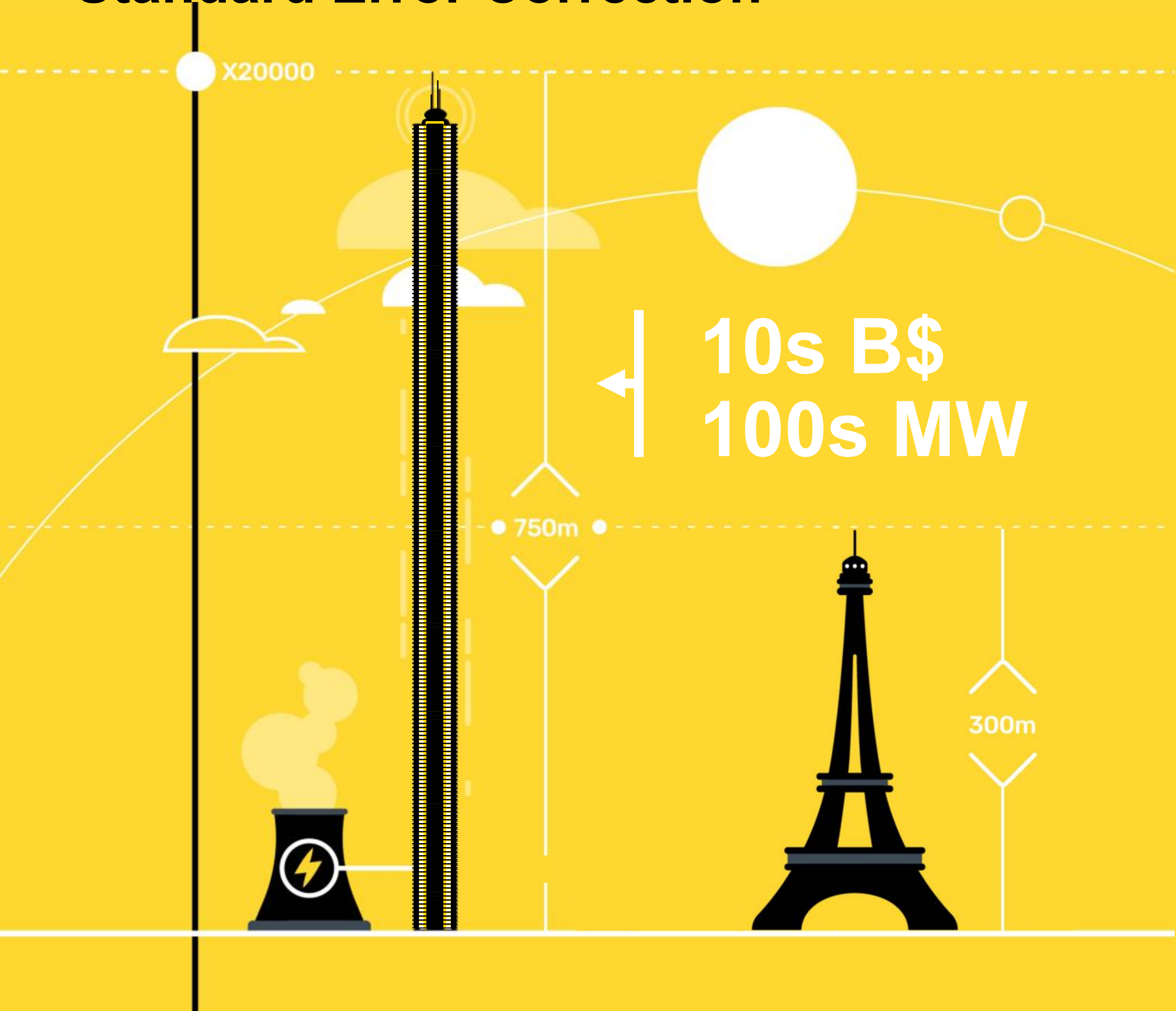


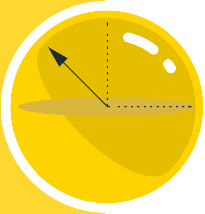
100 000
Physical Qubits



100
Logical Qubits

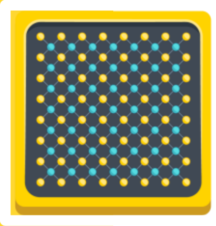
Run Shor's Algorithm on Standard Error Correction





20 000 000

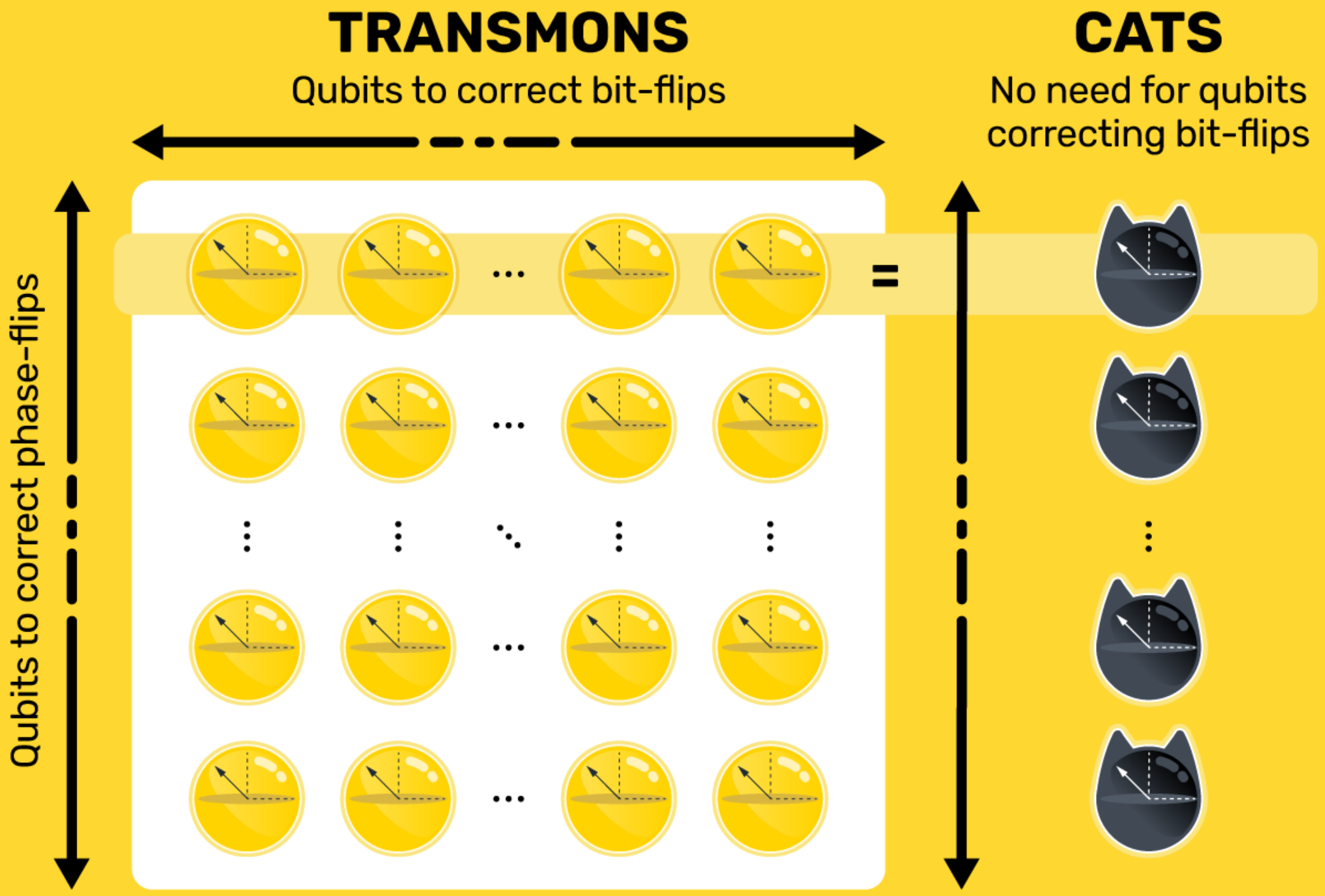
Physical Qubits



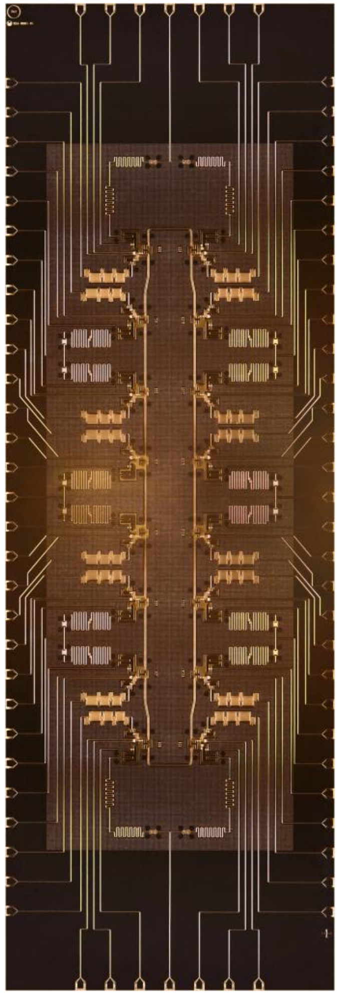
20 000

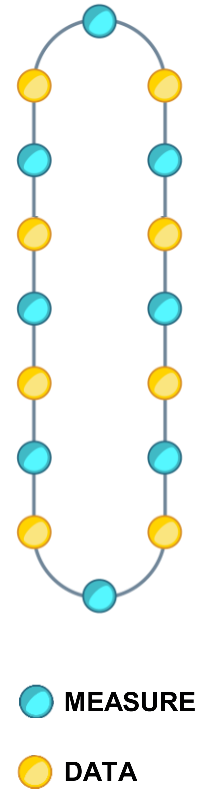
Logical Qubits

With Only One Error Left, Correction Can Be One-dimensional, Only Taking Care Of Phase Flips

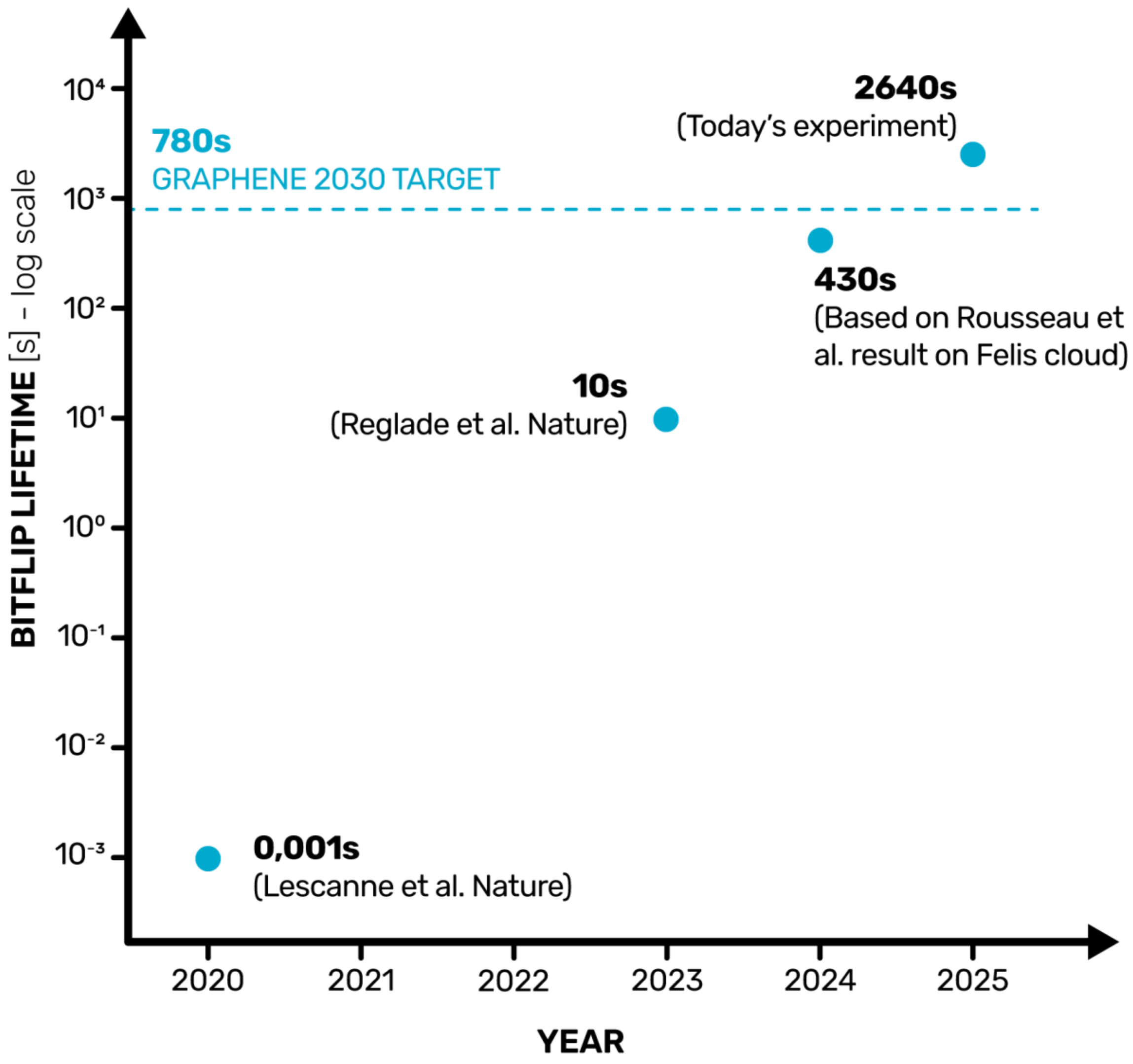


HELIUM, 16 CAT-QUBIT NOW IN TESTING

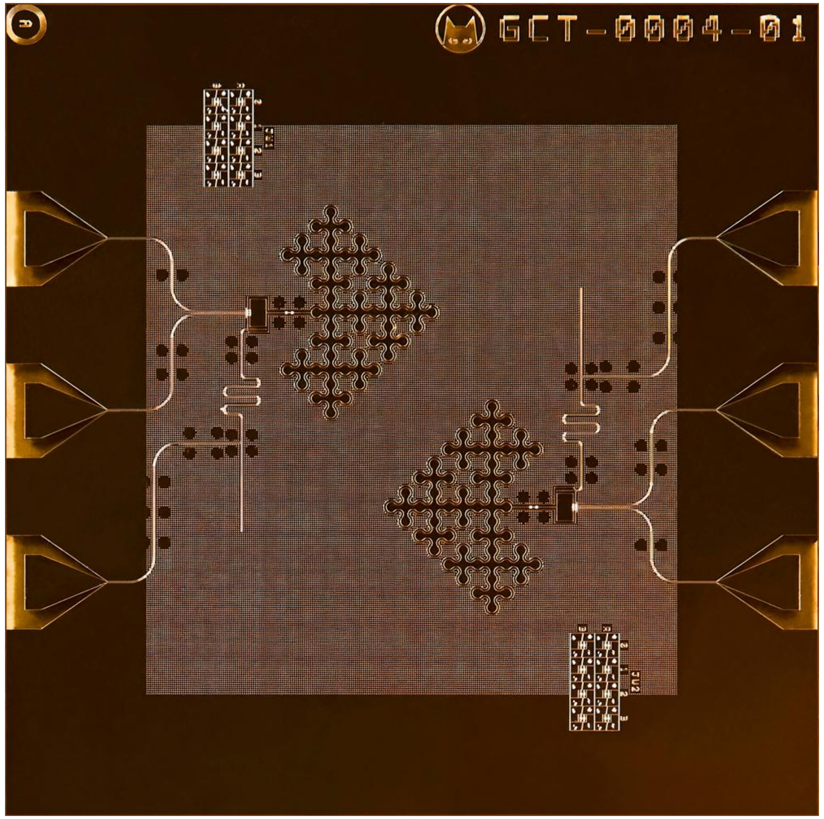




ALICE & BOB BIT-FLIP LIFETIME BY YEAR



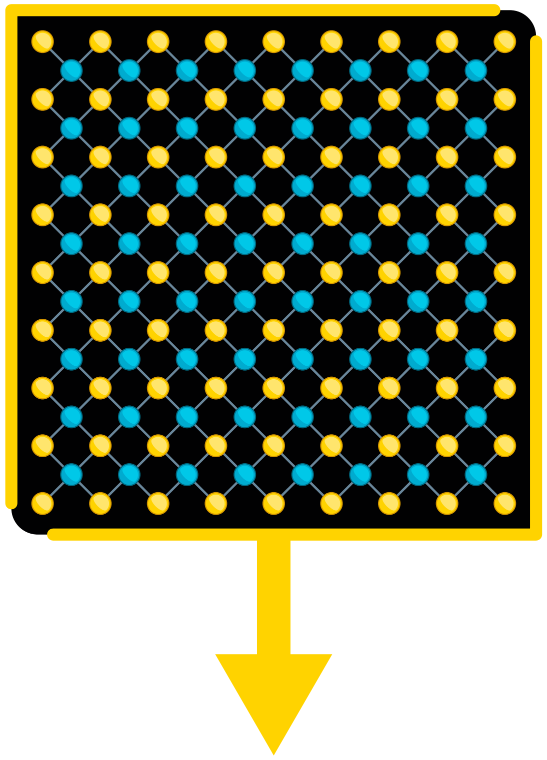
BOSON 4 SINGLE CAT-QUBIT ON THE CLOUD

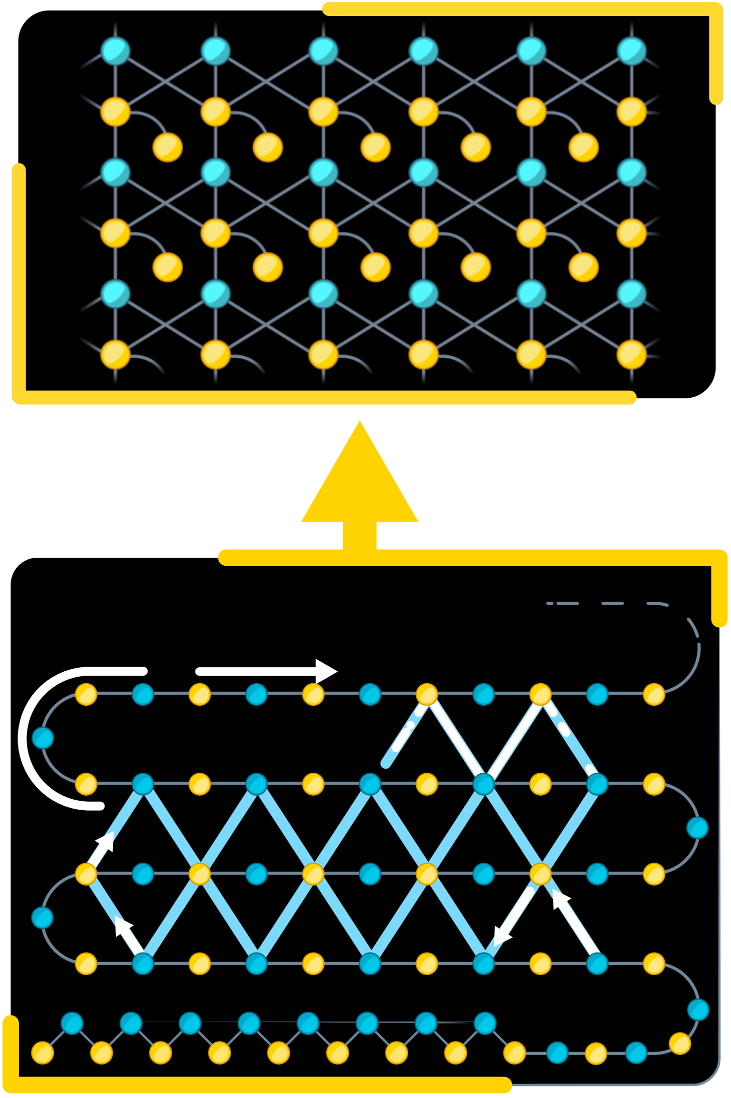


Cats Have One Dimension To Play With, Allowing For More Efficient Codes

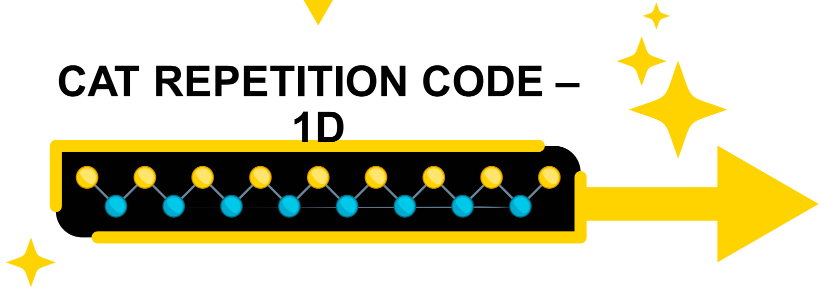
SURFACE CODE – 2D

CAT LDPC CODE – 2D[1]





CAT REPETITION CODE – 1D



1. *Diego R., et al. "LDPC-cat codes for low-overhead quantum computing in 2D" (2024)*

EXTRA CONNECTIONS BETWEEN DISTANT QUBITS

LESS PHYSICAL QUBITS PER LOGICAL QUBIT

200x REDUCTION

VS STATE-OF-THE-ART SURFACE CODE FOR SHOR

This is How a Useful Quantum Computer Could Become Practical Sooner

Standard approach[1]

Number of physical qubits

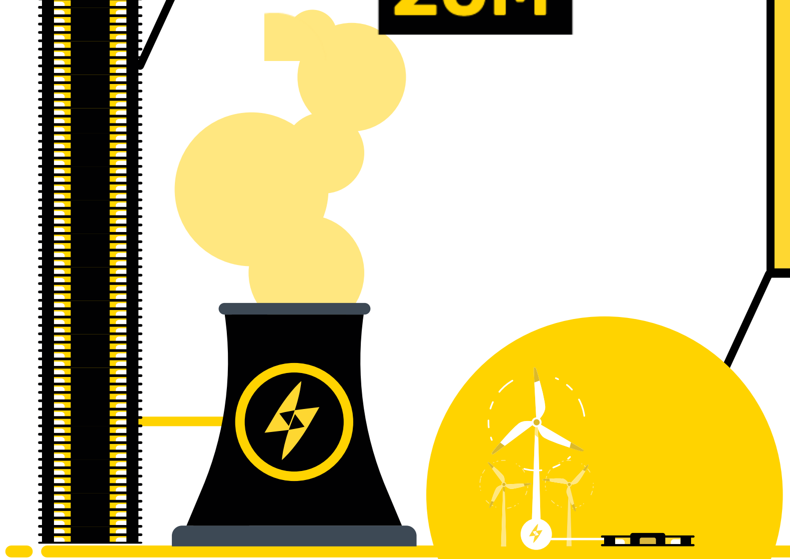
20M

The scale of a modern small data center

LDPC+Cats[2]

Number of physical qubits

100k



Read the full story: Alice&Bob roadmap

alice-bob.com/whitepaper-download

1. *Craig G. et al. "How to Factor 2048 Bit RSA Integers in 8 Hours Using 20 Million Noisy Qubits." Quantum 5 (2021)*
2. *Diego R. et al."LDPC-cat codes for low-overhead quantum computing in 2D" (2024)*

Alice & Bob's no detour roadmap to take-off

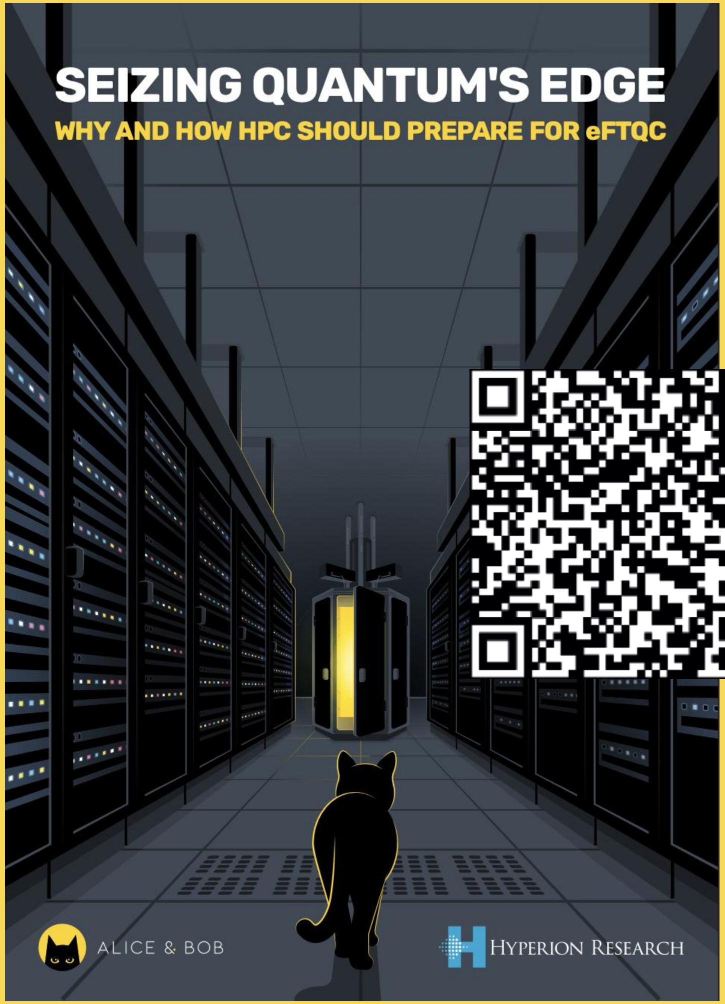
A concrete set of milestones to lead the quantum revolution

Unchallenged Quantum advantage[1]

	2024	2025	2026	2028	2030
	Milestone 1 Master the Cat Qubit	**Milestone 2** Build a Logical Qubit	**Milestone 3** Fault-Tolerant Quantum Computing	**Milestone 4** Universal Quantum Computing	**Milestone 5** Useful Quantum Computing
Cat Qubits	1	16	48	250	2000
# logical qubits	0	1	4	5	100
Error rate per logical qubit	N/A	10^{-2}	10^{-3}	10^{-4}	10^{-6}
	✓ Herd the Cats ✓ Achieve Record Bit-Flip Protection ✓ Run Cat Qubit Operations	➢ Mirror the Phase ➢ Count the Flips ➢ Link the Qubits	➢ Connect Logical Qubits ➢ Double the density ➢ Run a First Logical Gate	➢ Create Magical States ➢ Correct Errors, Live ➢ Build the Quantum Firmware	➢ Top Hardware Efficiency ➢ Switch Qubits ➢ Improve Enabling Technologies

Notes
1. Solving a meaningful problem using a quantum computer that classical computers cannot solve

New report



We introduce early FTQC (eFTQC)

100 – 1000 logical qubits

10^{-6} – 10^{-10} logical error rate

By 2030 Industry target

Main finding: significant impact on HPC

Materials science – **chemistry** – other **many-body problems**

13 – 54% of computational workloads in research-oriented HPC sites

→ The user base exists!

Staged roadmap to lead QC-HPC integration

1. **Co-design hybrid workflows** that overcome bottlenecks in critical HPC applications.
2. **Build an open software stack** for seamless integration of hybrid jobs.
3. **Deploy eFTQC QPU prototypes** to gain operational expertise and influence system design.

Focusing on proven computational advantage

	Problem Solved	Quantum Complexity	Classical Complexity	Computational speedup	Comments on logical qubit requirements for solving relevant-scale problems
QPE algorithm	Estimate eigenvalues of unitary operator	Polynomial for Hamiltonian simulation	Exponential in the general case for Hamiltonian simulation	**Up to exponential but context-dependent**	Condensed matter physics (e.g. Hubbard model with ≈100 logical qubits)[2-3] Quantum chemistry simulations with ≈1000 logical qubits[4]
Time evolution algorithm	Study dynamics of quantum systems	Polynomial	Exponential in the general case	**Exponential**	Evolution of system with ≈200 logical qubits for well-chosen problems[5-6]
Shor's algorithm	Integer factorization, discrete logarithm	$O(\{\log N\}^3)$ (basic implementation)	$\exp[\tilde{O}(\{\log N\}^{1/3})]$	**Superpolynomial[2]**	Cryptanalysis with ≈1000 logical qubits[7-8]
HHL algorithm	Solve system of linear equations	$O(\log N)$ (under assumption)	Polynomial, typically $O(N^3)$	**Exponential (under restrictive conditions)**	Potential applications in data analysis or differential equations, but difficult to preserve exponential speedup in end-to-end settings[9-10]
Grover's algorithm	Unstructured search	$O(\sqrt{N})$	$O(N)$	**Quadratic**	Quadratic speedups are not enough for practical advantage[11-12]

2. The speedup provided by Shor's algorithm is exponential for discrete logarithms on elliptic curves, but superpolynomial for integer factorization.

Materials science simulations are the strongest candidates to benefit from eFTQC

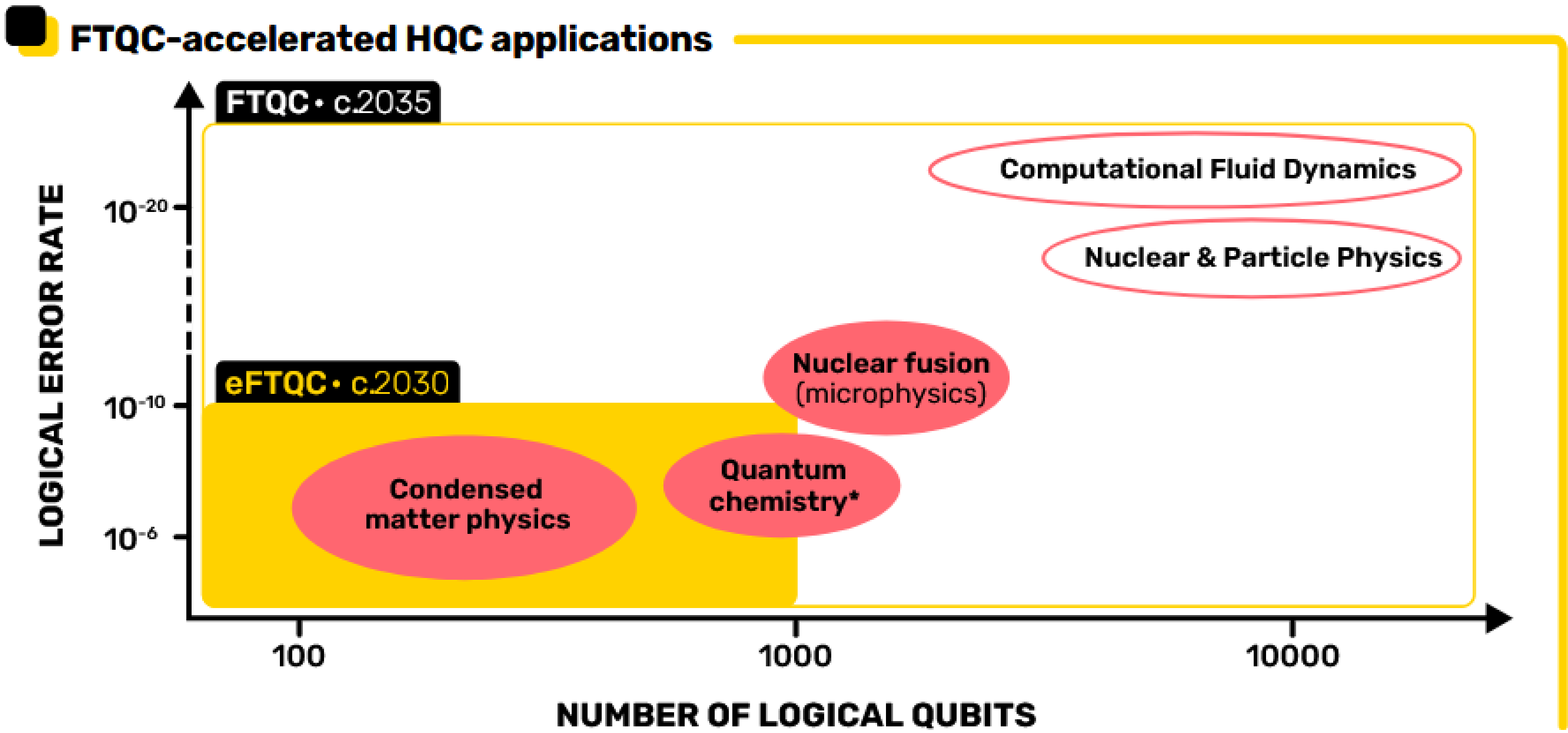


Figure 3 - FTQC acceleration roadmap: anticipated HPC application domains and timelines based on logical qubit counts and error rate thresholds. Timelines are based on quantum computing vendor roadmaps.

* Cryptanalysis using Shor's algorithm demands quantum hardware resources on par with those required for quantum chemistry workloads.

Quantifying the impact of eFTQC acceleration on HPC workloads

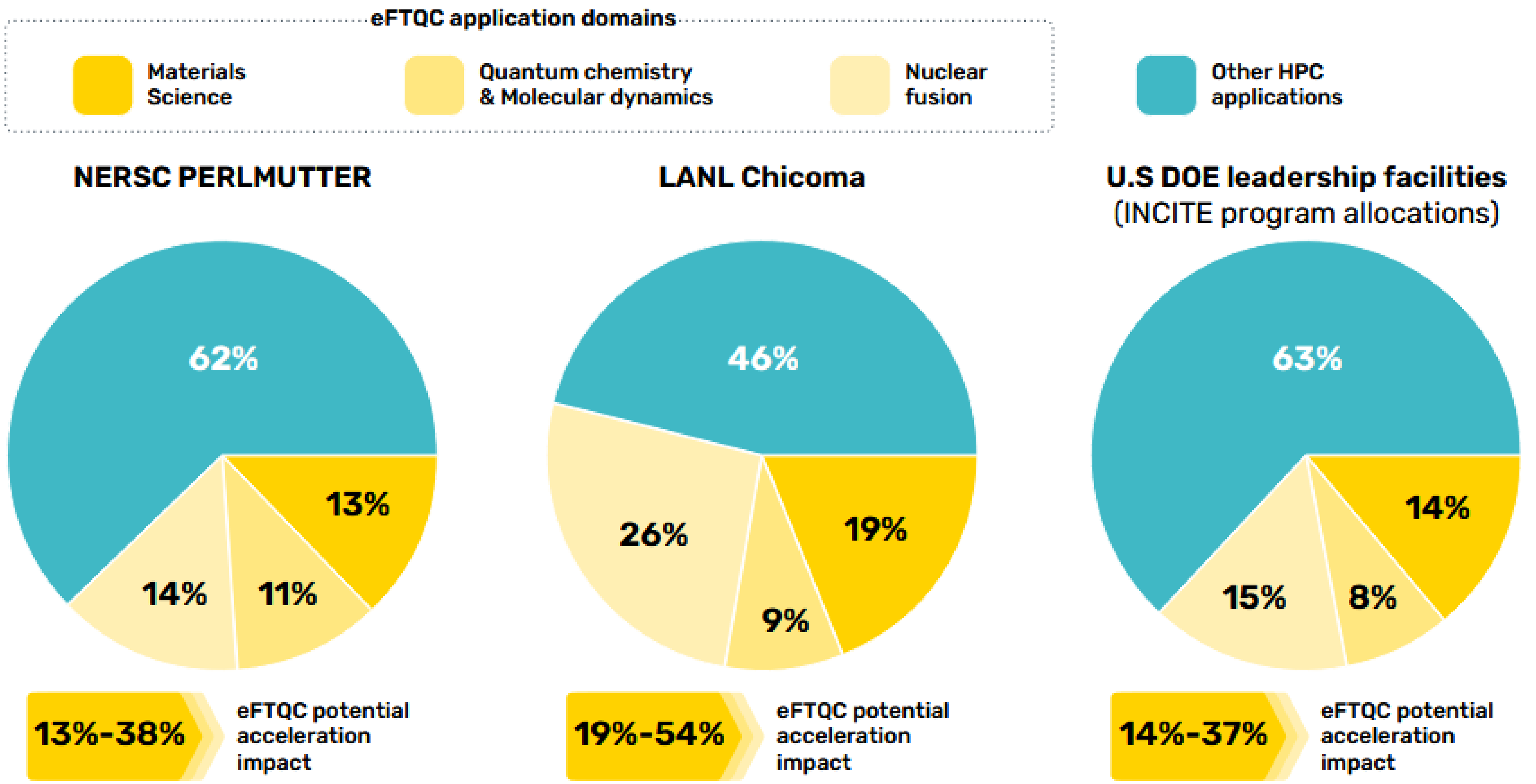


Figure 4 - Analyses of different supercomputing usages[22-24] suggest that eFTQC will accelerate a significant part of existing HPC workloads

The quantum frontier is moving: more HPC applications could enter the reach of eFTQC

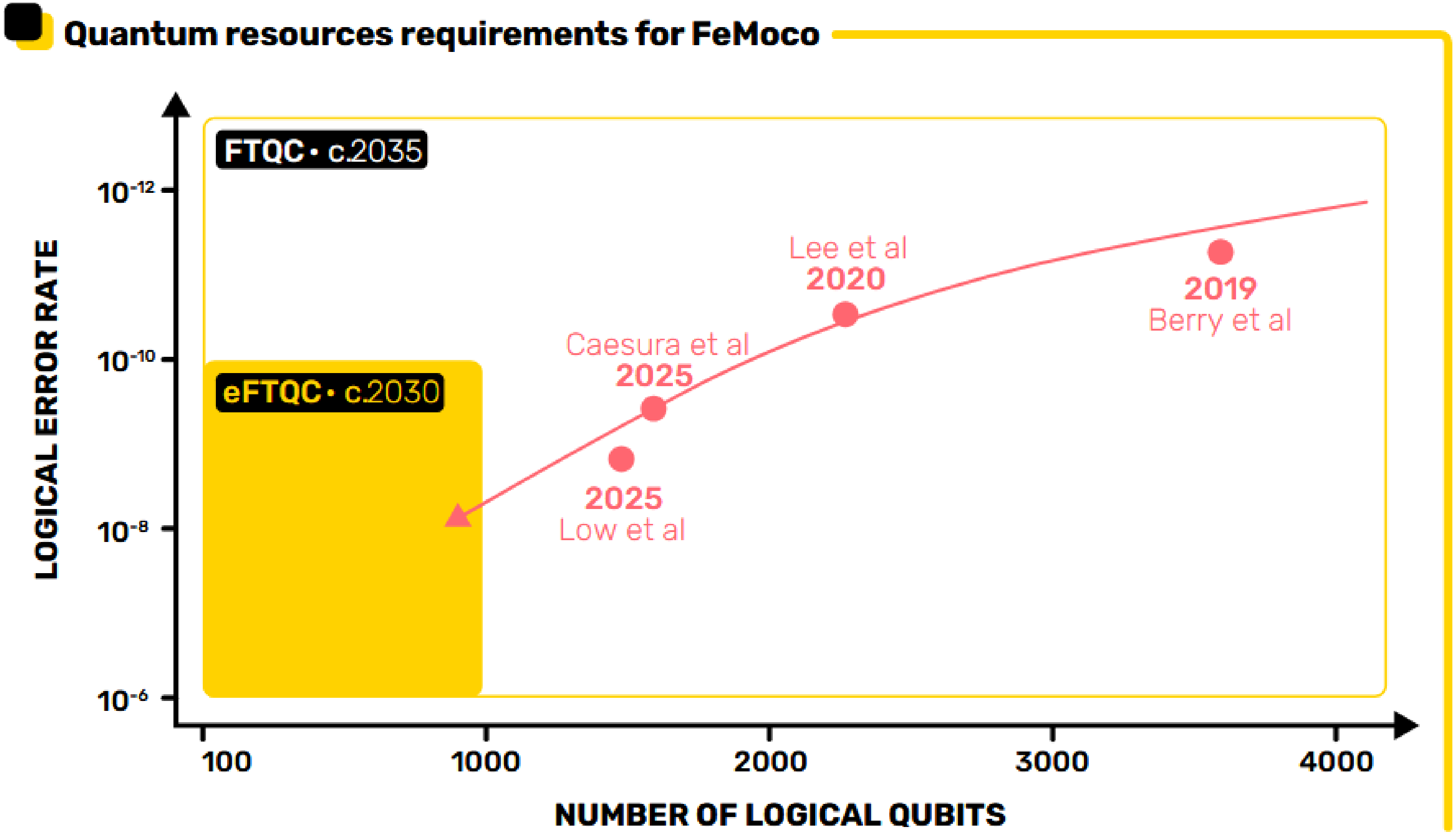


Figure 5 - evolution of logical resource requirements for simulating FeMoco illustrating that quantum algorithms advances bring the problem closer to the realm of eFTQC. See Appendix 5 for detailed data.

Strategic considerations for HPC centers

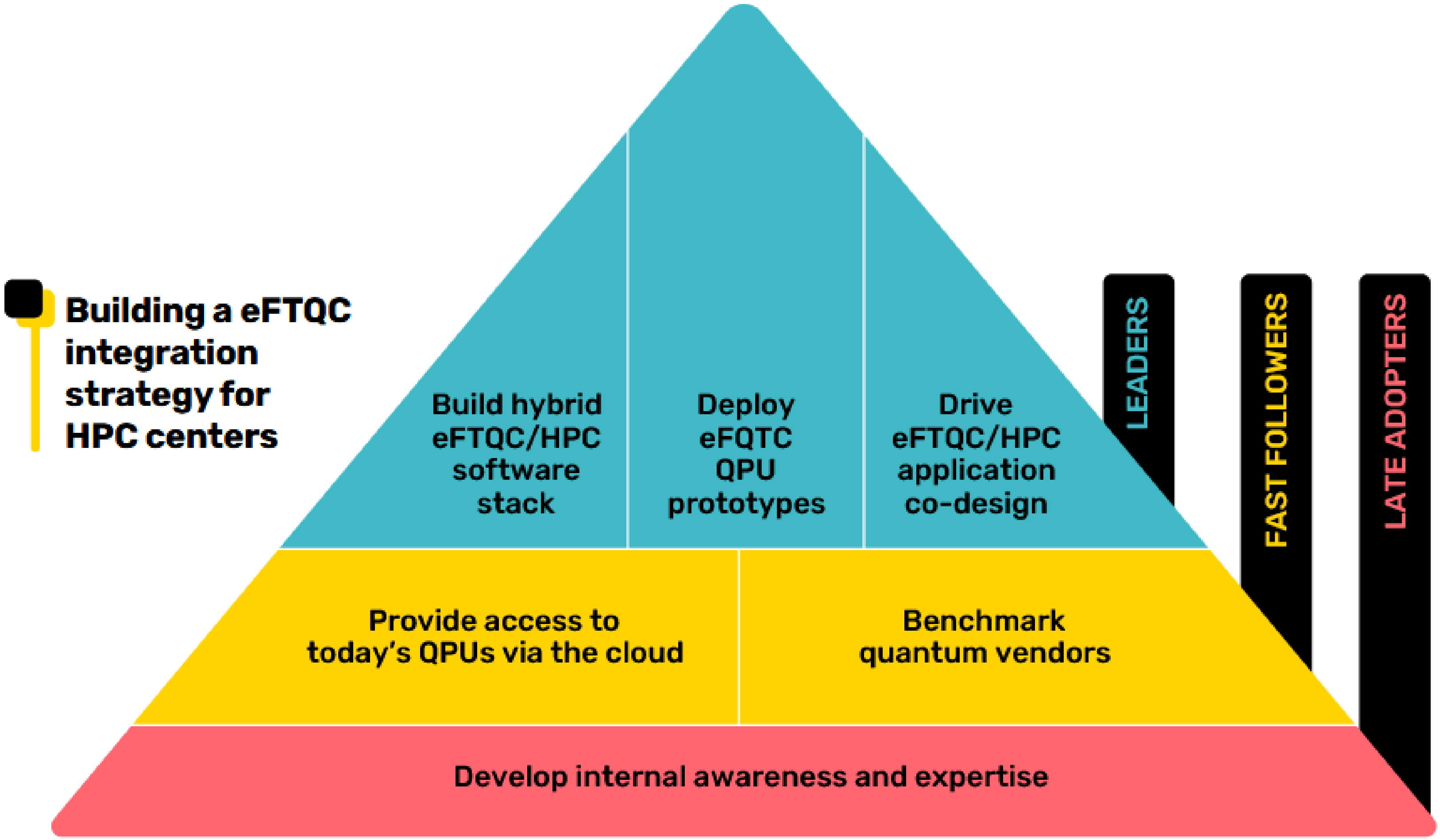


Figure 7 - Readiness spectrum for eFTQC adoption in HPC: from developing quantum awareness to leading the integration of eFTQC QPUs into HPC sites by 2030.

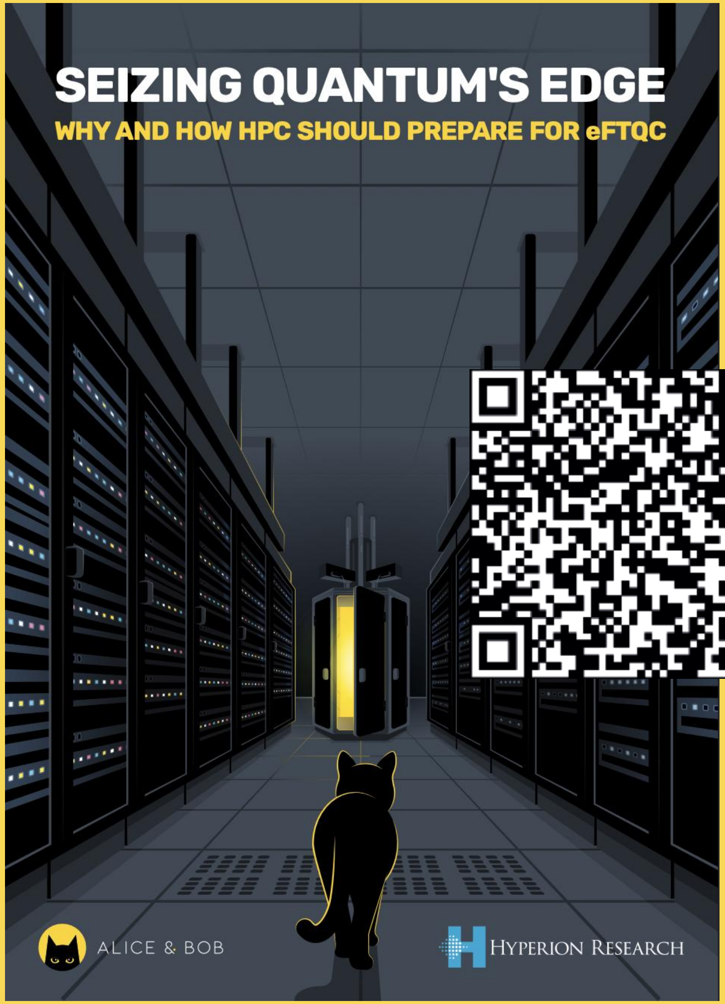
APPENDIX 3 – HPC applications and the potential impact of eFTQC

HPC application area	High level description	Classical computational methods, tools and libraries	Impact of early fault-tolerant QPUs
Materials science	Simulating and predicting material properties (e.g., conductivity, magnetism, phase transitions).	DFT, TDDFT, Tight-binding methods, GW approximation, Molecular dynamics, DMFT	Probability of eFTQC impact: **SURE**
Quantum chemistry and Molecular dynamics	Simulations of molecular systems to compute energies, reaction pathways, molecular properties and study atomistic time evolution.	DFT, CCSD(T) (Coupled Cluster), Perturbation theory (MP2), DMRG, Hartree-Fock, Force field, Gromacs, NWChem, Molecular dynamics	Probability of eFTQC impact: **HIGH**
Nuclear fusion	Simulations of ionized matter to model plasma behavior in fusion devices, space, and astrophysical environments, including fluid, kinetic, and microphysical processes.	PIC, TDDFT, MHD solvers, GENE code	(for microphysics modeling only)
Nuclear and Particle Physics	Studies fundamental particles and their interactions, often at high energies, such as those in particle accelerators	Lattice QCD, Monte Carlo	
Computational fluid dynamics	Simulation of fluid flows (air, water, combustion) in engineering (e.g. aircraft design) and physics.	Navier-Stokes solvers,Lattice Boltzmann methods, OpenFOAM, ANSYS Fluent	
Astrophysics	Simulations of stars, galaxies, black holes, universe evolution	N-body simulations, CASTRO,	
Biosciences	Model biological processes at cellular/molecular scales (including protein structure prediction) and High-Throughput Screening (HTS).	BLAST, DOCK, Rosetta, alphafold, Abyss	Probability of eFTQC impact: **MEDIUM**
Structural modeling	Simulate how structures deform and respond under forces (stress, strain, vibration, failure).	Finite Element Methods	
Climate modeling	Simulates atmospheric and ocean systems.	WRF and CESM / CCSM	
Geosciences	Reservoir simulation (oil and gas).	Finite / Spectral Element Methods	
Finance	Portfolio optimization, market dynamics simulation.	Monte Carlo, stochastic differential equations, PDE	Probability of eFTQC impact: **LOW**
Operations research	Scheduling, logistics, infrastructure design.	Mixed Integer Linear Programming, Gurobi	
AI	Training of Deep Learning models (LLMs, computer vision, PINNs), often specialized for scientific or engineering domains listed above.	PyTorch, TensorFlow	

APPENDIX 4 – Detailed quantum resource estimates necessary for HPC applications listed in Appendix 3, when available

HPC application area	Sub problem example	Number of logical qubits	Number of logical operations (T gates)	References
Materials science (condensed matter)	Fermi-Hubbard	≈ 100-1000	$10^6 - 10^8$	Babbush et al., 2018[27] Kivlichan et al., 2020[28] Campbell et al., 2022[2] Childs et al., 2017[29] Flannigan et al ., 2022[30]
	Spin models	≈ 100	$10^5 - 10^9$	
Quantum Chemistry and Molecular Dynamics	Calculate ground state energies of molecular systems	≈ 1000	$10^9 - 10^{12}$	Goings et al., 2022[19] Low et al., 2025[31]
Nuclear fusion	Microphysics modeling (first-principles stopping calculations)	≈ 1000	$10^{15} - 10^{17}$	Rubin et al., 2023[21]
CFD	Estimate the drag force for the flow-past-a-sphere problem	≈ 1000-10000	$10^{20} - 10^{24}$	Penuel et al., 2024[32] Jennings et al., 2024[33]
Nuclear and Particle Physics	Lattice QCD	$10^5 - 10^6$	$10^{21} - 10^{27}$	Rhodes et al., 2024[34]
Cryptanalysis	Factorization of 2048 bit RSA integer	≈ 1000	$10^9 - 10^{12}$	Gidney, 2025[8]

New report



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