



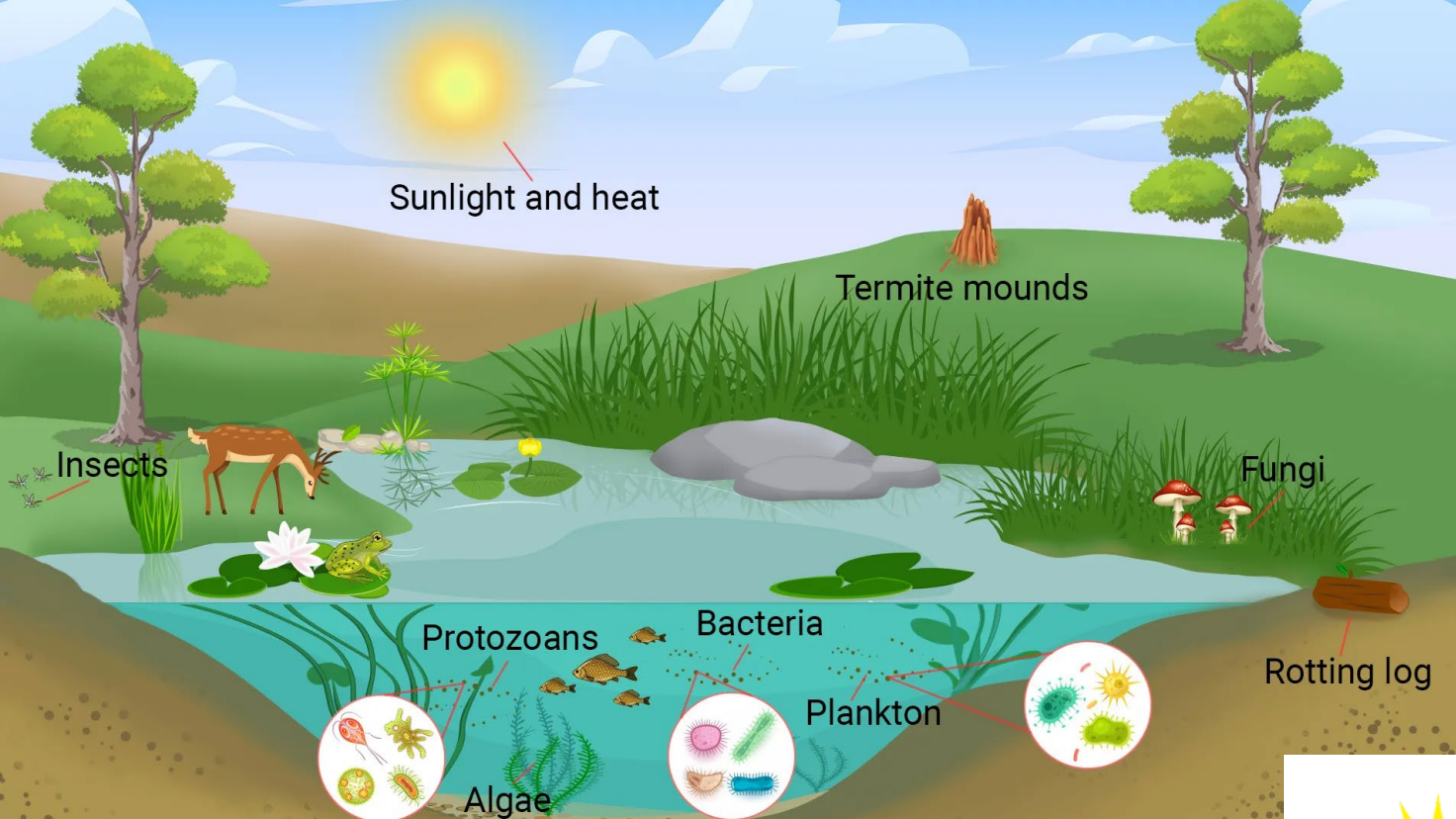
미국의 양자 생태계 현황

2025. 01. 09.

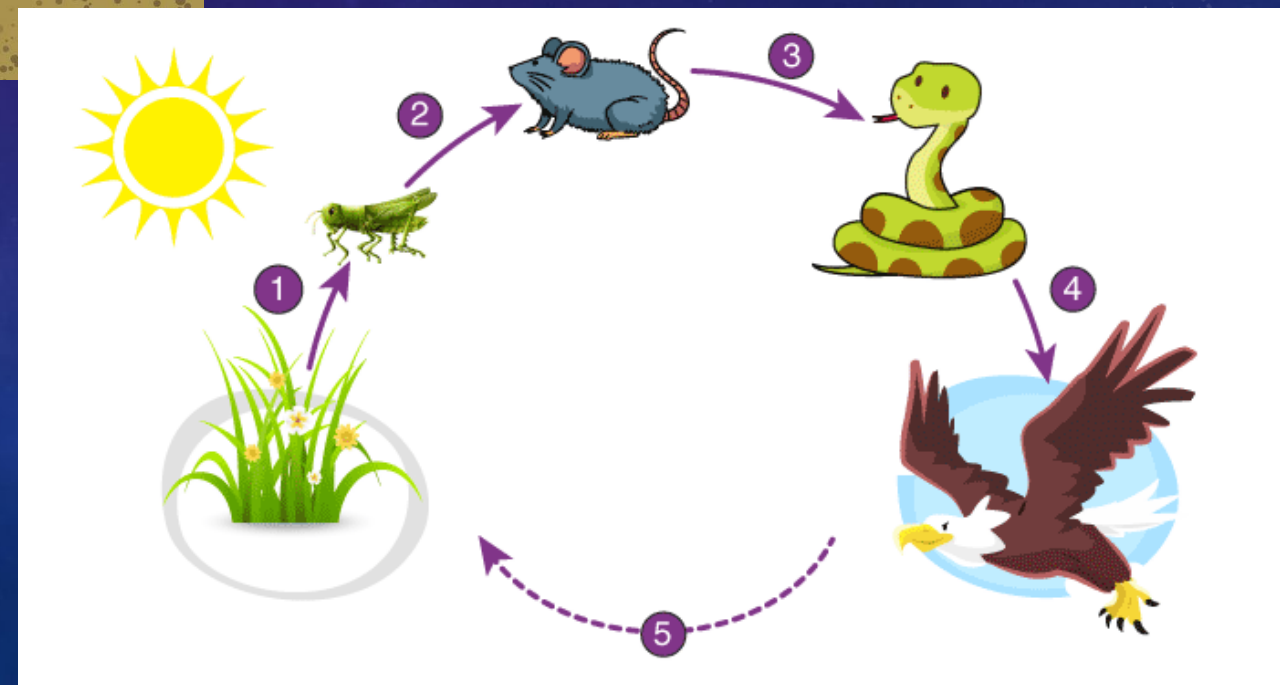
한-미 양자기술협력센터

정윤채

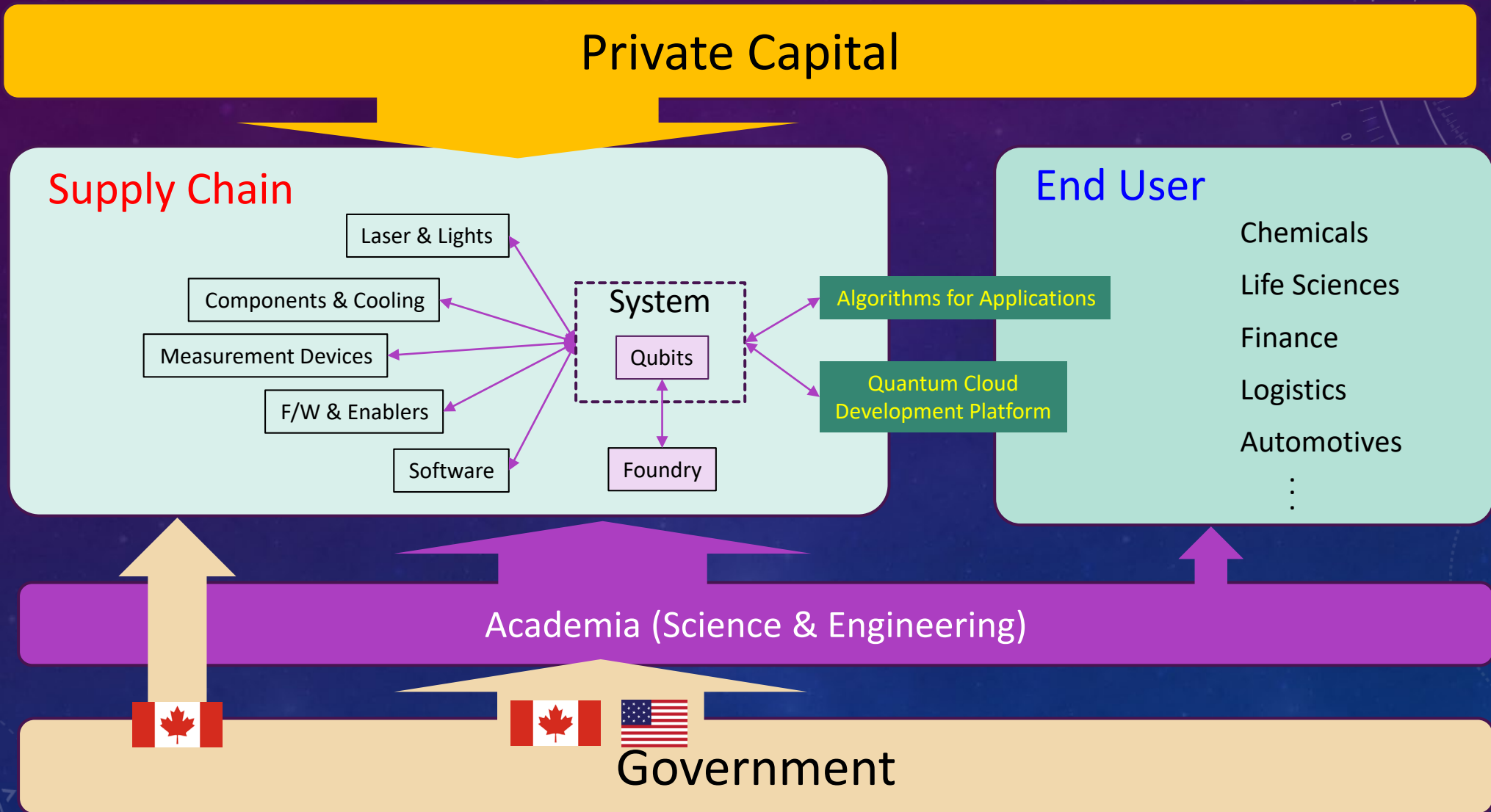
Ecosystem



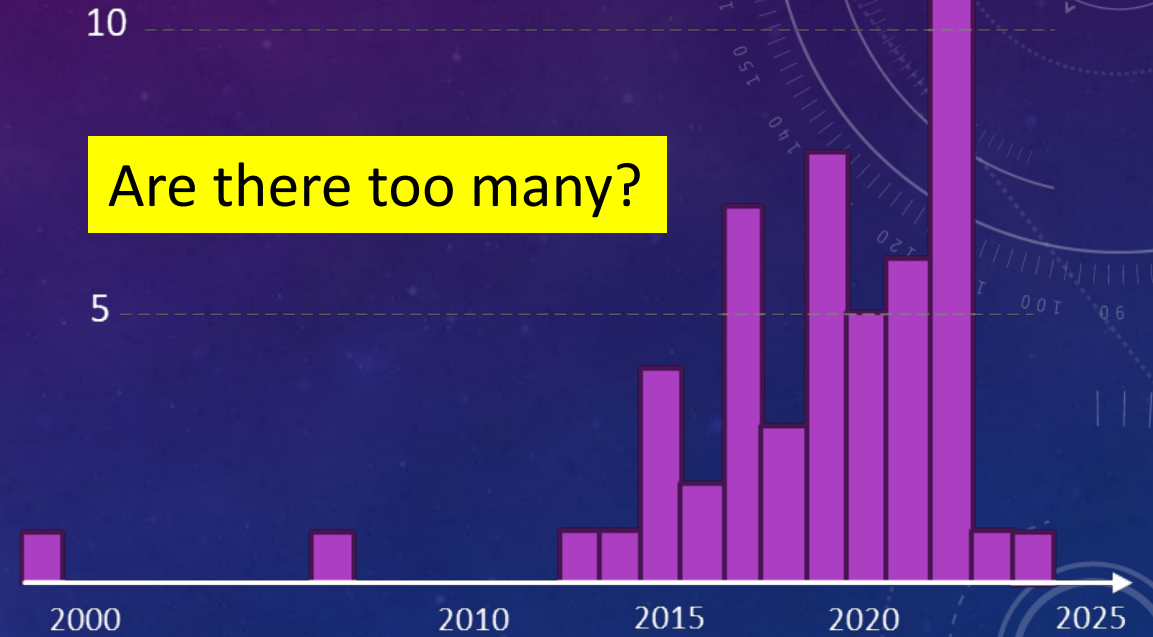
Ecosystem
is
"Interactive"



Quantum Ecosystem (computing)



Quantum Ecosystem – Investment & Qubits



"Qubit" Companies**

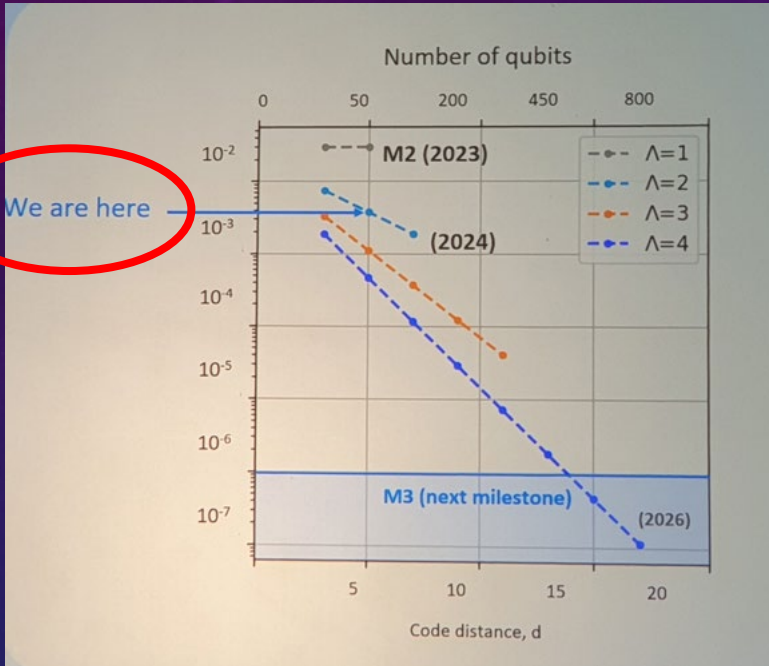
Startup Investment*

* McKinsey Report 2024

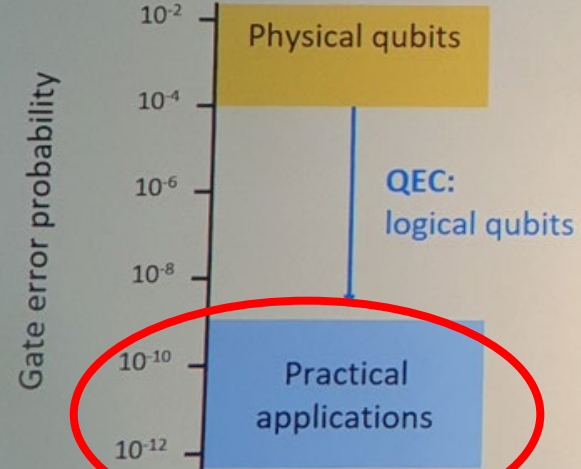
** The Quantum Insider

Quantum Ecosystem – Qubits

Error Correction



Hardware goal
Build qubits with gate error $\sim 10^{-10}$



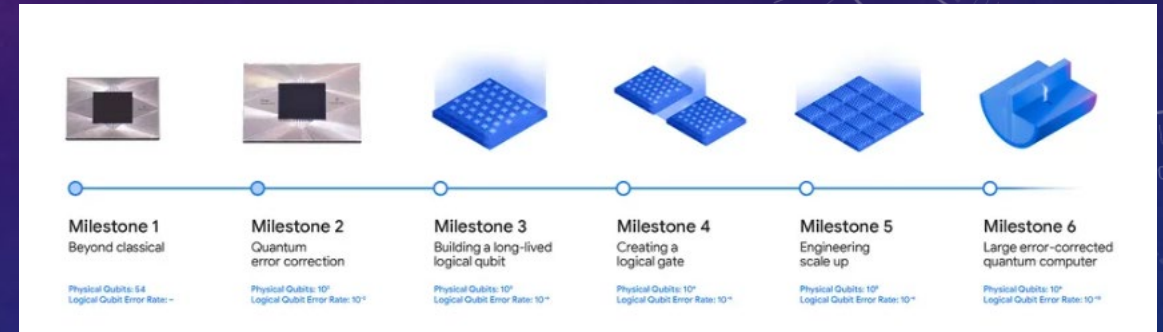
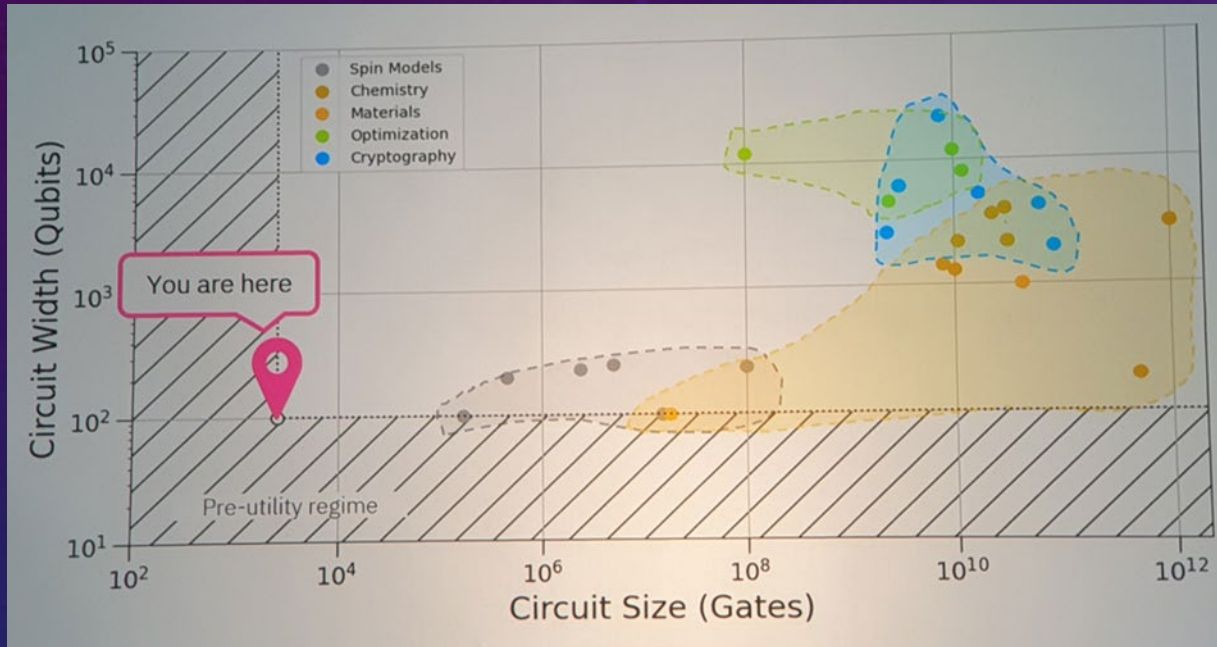
“Good progress, but further to go toward Practical Applications”

Quantum Ecosystem – Qubits

Scale-up : toward practical and useful applications

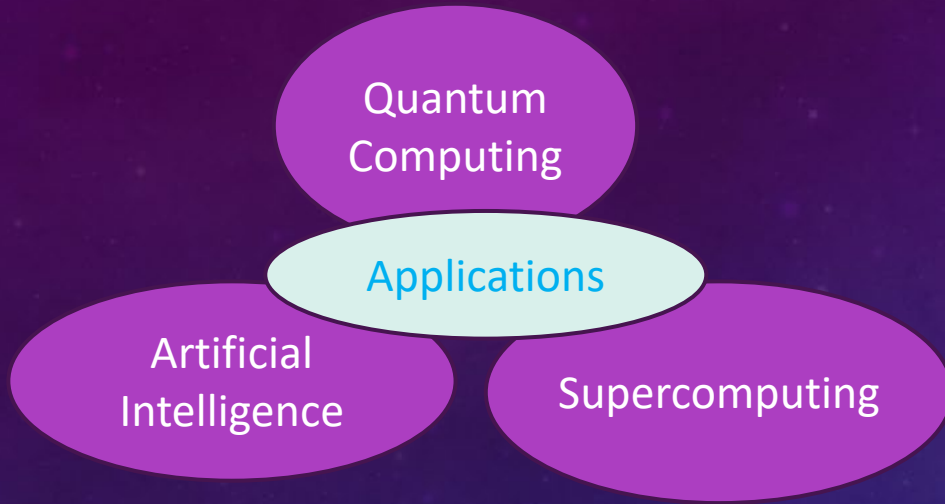
“More qubits, longer gates”

Roadmap announcement: 16 companies



	2023	2024	2025	2026	2027	2028	2029	2033+	
Enhancing quantum execution speed by 5x with quantum serverless and Execution modes	Enhancing quantum execution speed by 5x with quantum serverless and Execution modes	Improving quantum circuit quality and speed to allow 5K gates with parametric circuits	Enhancing quantum execution speed and parallelization with partitioning and quantum modularity	Improving quantum circuit quality to allow 7.5K gates	Improving quantum circuit quality to allow 10K gates	Improving quantum circuit quality to allow 15K gates	Improving quantum circuit quality to allow 100M gates	Beyond 2033, quantum-centric supercomputers will include 2000's of logical qubits unlocking the full power of quantum computing	
Platform	Code assistant	Functions	Mapping Collection	Specific Libraries				General purpose QC libraries	
Middleware	Quantum Serverless	Translator Service	Resource Management	Circuit Knitting xP	Intelligent Orchestration			Circuit Libraries	
Execution Modes	Heron (5K) Error Mitigation 5k gates 133 qubits Classical modular 133x3 – 399 qubits	Flamingo (5K) Error Mitigation 5k gates 156 qubits Quantum modular 156x7 – 1092 qubits	Flamingo (7.5K) Error Mitigation 7.5k gates 156 qubits Quantum modular 156x7 – 1092 qubits	Flamingo (10K) Error Mitigation 10k gates 156 qubits Quantum modular 156x7 – 1092 qubits	Flamingo (15K) Error Mitigation 15k gates 156 qubits Quantum modular 156x7 – 1092 qubits	Starling (100M) Error correction 100M gates 200 qubits Error corrected modularity	Blue Jay (1B) Error correction 1B gates 2000 qubits Error corrected modularity		

Quantum Ecosystem – Quantum Classical Hybrid

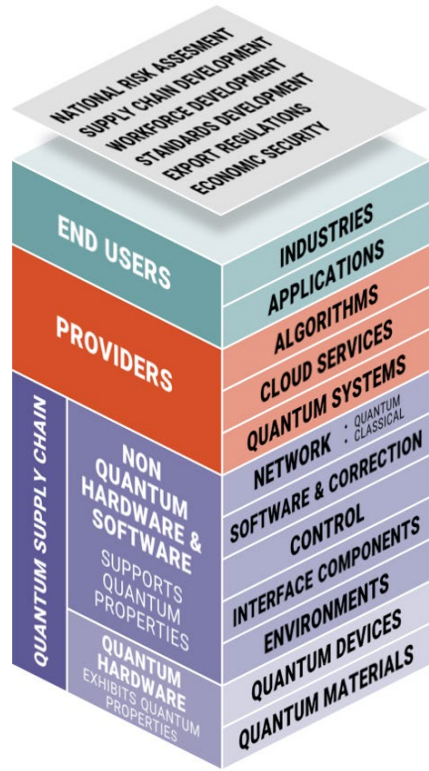


- Use SC/AI for QC HW design/error correction
- Use QC to enhance machine learning
- Use QC as an accelerator of SC

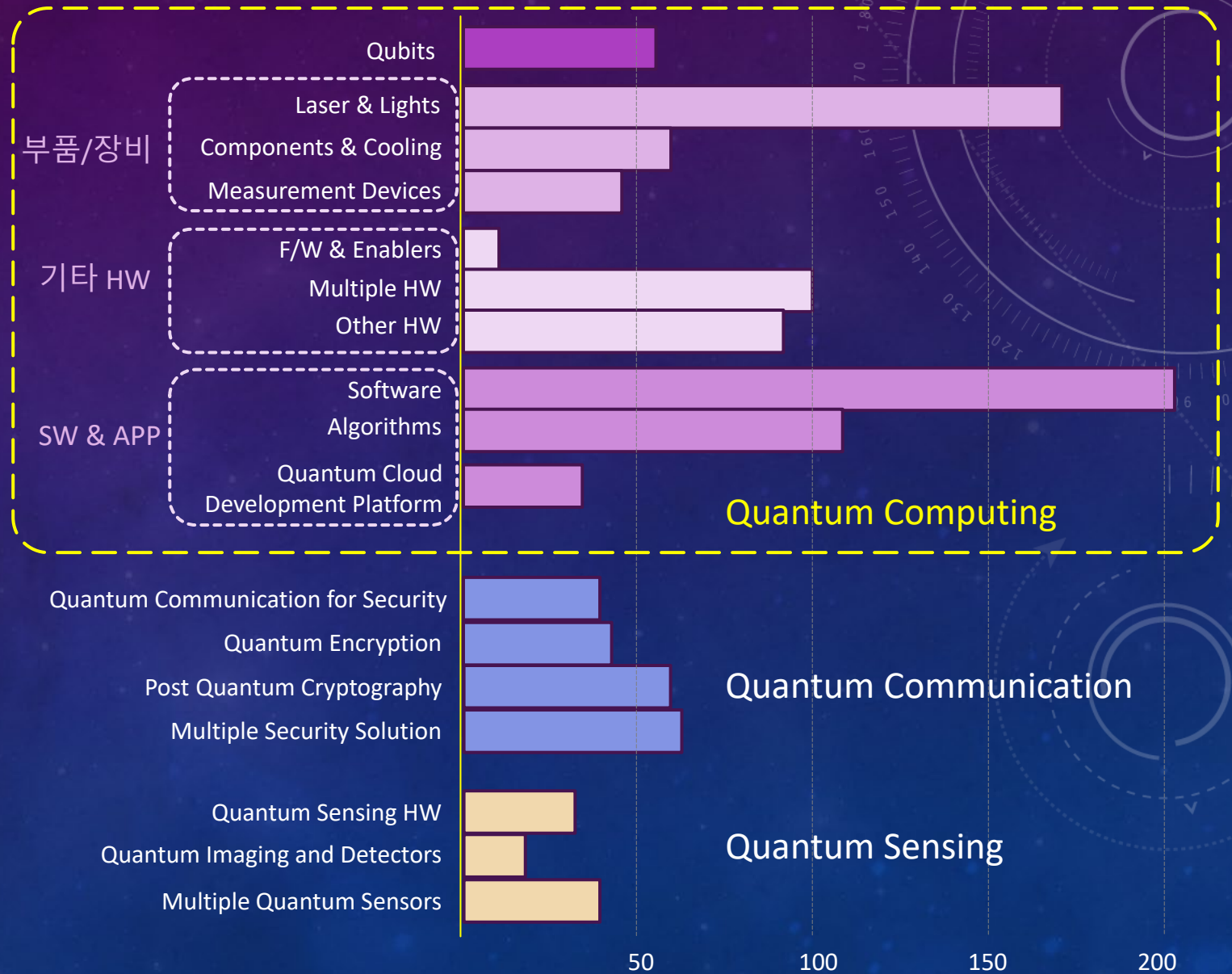
- Supercomputing centers are considering hybrid systems
- Major qubit companies are announcing their hybrid capabilities
- NVIDIA offers SW stacks for hybrid architecture (CUDA-Q)
- To explore **Practical Applications** even with **NISQ**

Quantum Ecosystem – Supply Chain

The Quantum Stack Policy and Strategy



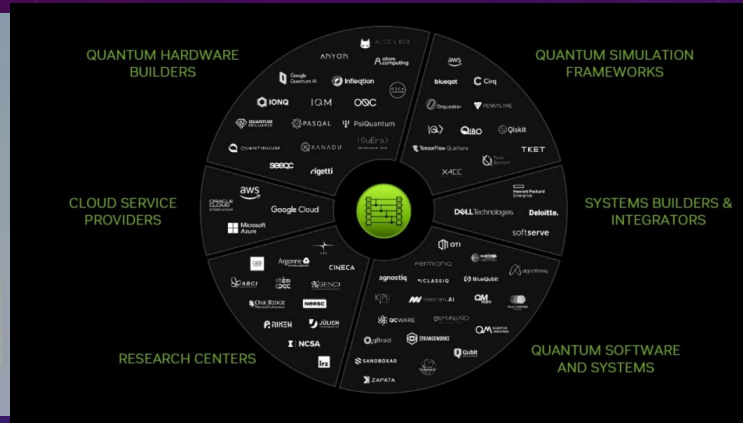
Supply Chain



Quantum Ecosystem – Alliances and Partnership



<p>Drug discovery Cytochrome P450 (anti-target) PNAS 119, 2203533119 (2022)</p>	<p>Battery design LiNiO₂ (cathode material) PRX Quant. 4, 040303 (2023)</p>	<p>Heterogeneous catalysis Polyurethane synthesis arXiv:2312.07654 (2023)</p>
<p>Fusion reactor design PNAS 121, e231772121 (2022)</p>	<p>Simulating classical oscillators PRX 13, 041041(2023)</p>	<p>Classical optimization arXiv:2408.08292</p>



NVIDIA

IBM Quantum Network

Global community driving innovation

250+	41
Organizations in the IBM Quantum Network	Quantum Innovation Centers, 8 with Dedicated Service
125+	50+
Members of QICs Research centers and universities	Industry clients – includes Quantum Accelerator, Premium Plan, Industry QIC members
45+	10+
Startups	Ecosystem partners – includes re-sellers, OSIs, and ISVs

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IBM

Google

Partnership	Partners / Customers
End-User Pool (Public and Private)	AIRBUS, BASF, Capgemini, CINECA, COMMERZBANK, EDF, gesda, KIPU, LG, MBDA, Panasonic, PINQ, posco, SAFFRAN, Sumitomo Corporation, TATA, THALES
Cloud Access & Remote HPC	aws, Microsoft Azure, GENCI, CINECA, TCOC, Google Cloud, OVHcloud, JÜLICH
Development of Application Portfolio & Software Stack	Boehringer Ingelheim, Capgemini, KIPU, Mila, NVIDIA, ODYSSEY, parityq, Qubit, Schrodinger, SIEMENS, Sumitomo Corporation, Tech Mahindra, TCS, universität innsbruck
Programming Environment (QC Framework and Open-Source Library)	Atos, Google

Pasqal

NOVERA Partner Program

Novera QPU customers who need control systems, a dilution refrigerator, and quantum computing software tools can leverage our network of partners to streamline their journey for selecting and integrating their preferred technology with the Novera QPU.

Partners include: QM QUANTUM MACHINES, Maybell, river lane, OXFORD INSTRUMENTS, BLUE FORS, horizon quantum, QBLOX, Q-CTRL, QuantrolOX, CLASSIQ, ParTec, QANTUM ELEMENTS, STRANGE WORKS, Zurich Instruments, TREQ, qruise, rigetti.

Rigetty

And many more...

They claim their partnership as the ecosystem for "practical application"

Quantum Ecosystem – US Government

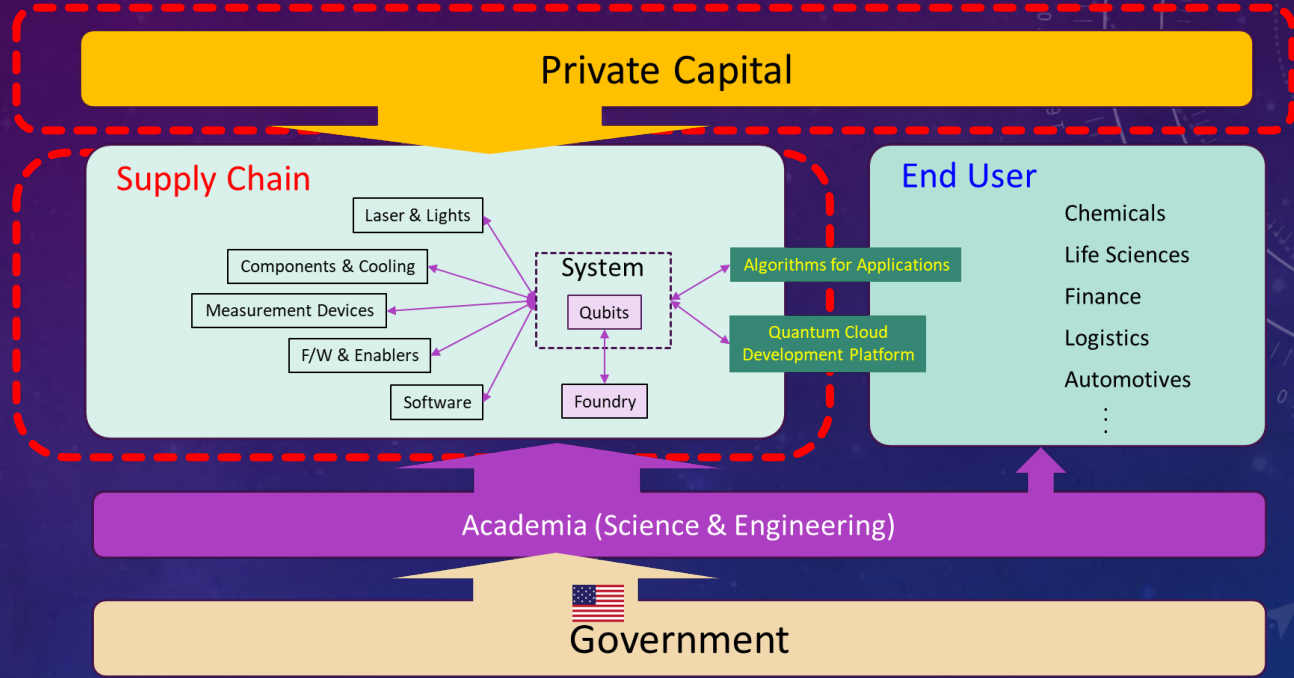
DOT : Outbound Investment Control ('24.10)

DOC : Export Control ('24.09)

- DOS : QDG ('24.07)
- NQCO : MDQ ('22.11)

↑
Control

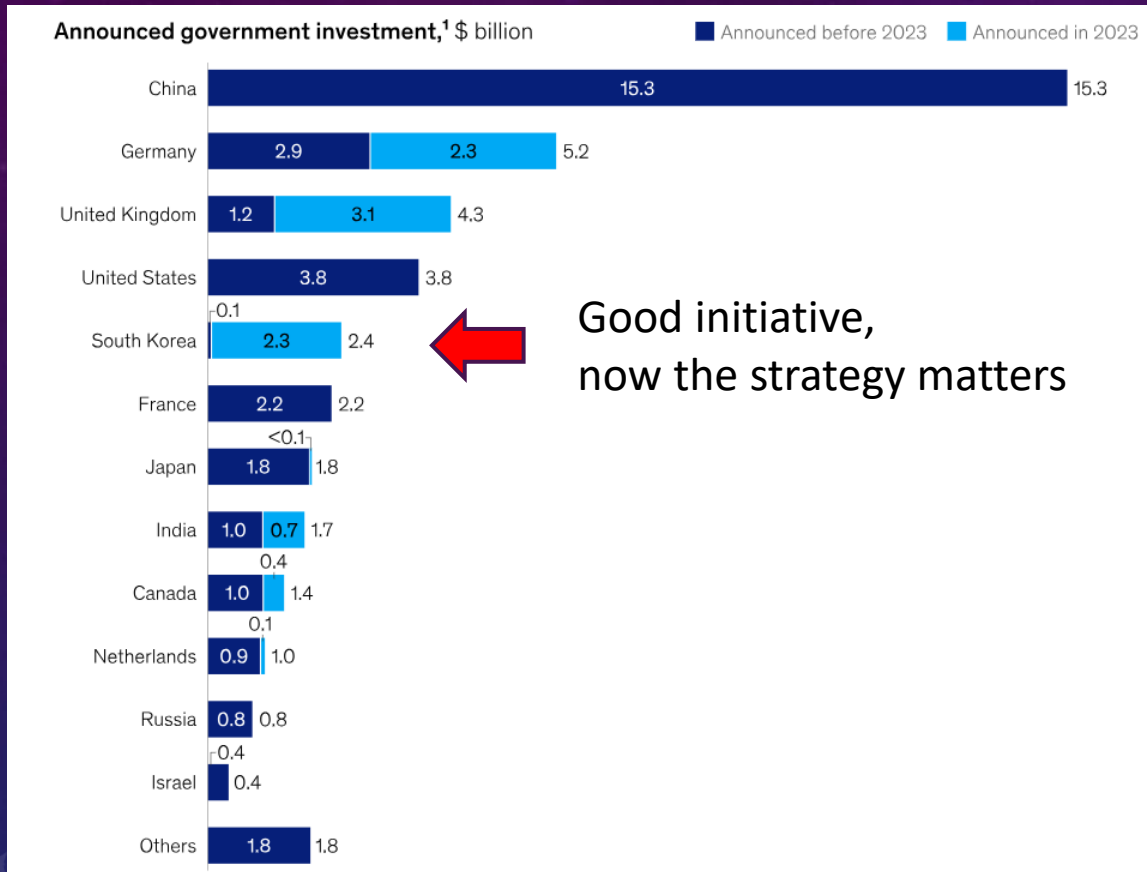
Promotion →



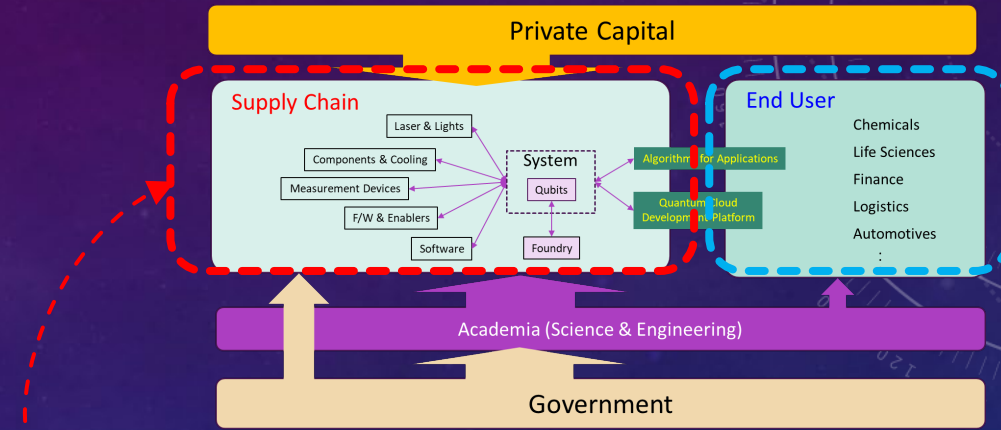
NQI Act Phase 2

- Name: Quantum Information Science, **Engineering, and Technology**
- Forster environment for **industrial** development
- Strengthen international cooperation with **key partners**

Quantum Ecosystem: What should we do?



McKinsey Report 2024



Where is the **current** battlefield?

Where will be the **future** battlefield?

When is the “**future**”?

시사점

- 과학과 산업이 **동시에 발전**하고 있으며 속도가 **매우 빠르게** 진행
 - 경쟁은 과학 뿐 아니라 산업에서 가열되고 있음
 - 느리게 움직이면 **공급망**에 참여할 기회가 없을 우려
- 현재 보이는 모습이 전부가 아닐 수도 있음
 - 보이는 것이 아니라 **보이지 않는 것에서 기회를** 찾아야 함
 - Yet to come: **소형화, 대규모화, 다양한 응용**

Mainframe vs. PC
 Local storage vs. Datacenter
 Voice phone vs. Smart phone

• 집중 투자 필요 분야

- **미래 기술**
- **공급망 참여** 가능 기술
- **응용 기술**
- Quantum Literacy
- Multidisciplinary Workforces
- Startup Incubation

감사합니다