Moonshot International Symposium for Goal 6

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Large-Scale Silicon Quantum Computer

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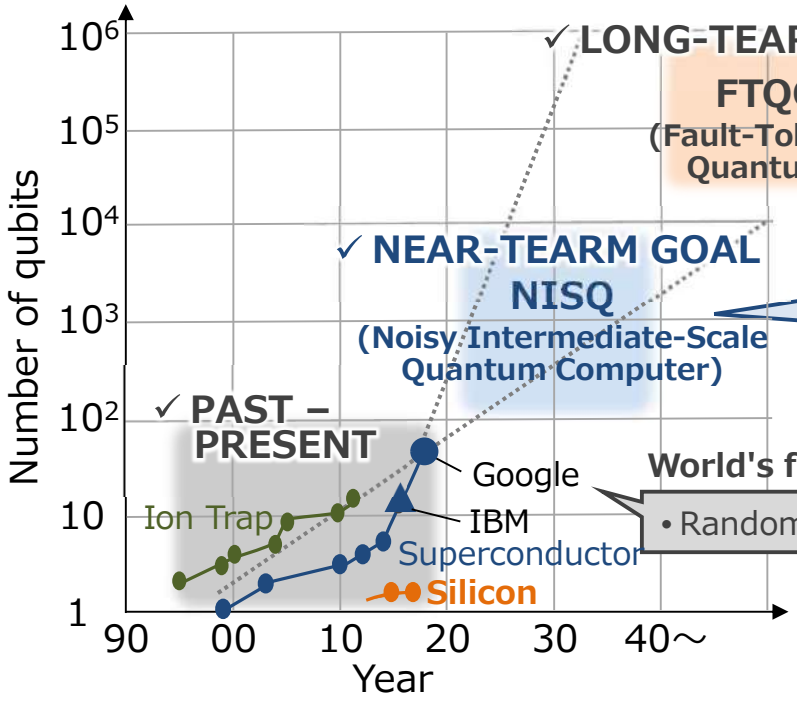
Hiroyuki Mizuno

Senior Chief Researcher
Center for Exploratory Research (CER)
Hitachi, Ltd.

hiroyuki.mizuno.vp@hitachi.com

Quantum Computer (QC) Development

- Silicon QC is expected to achieve large-scale one because of their potential for scaling.
- However, the gap between Si and superconductors is increasing in terms of # of qubit.
- We need to rethink the purpose of using silicon technology.



Many algos. But no hardware to run these algos

- Factorization (1994, Shor)
- Searching (1996, Grover)
- Options Pricing (2019, IBM & JP Morgan)

etc

R&D investment in the NISQ algorithm has been increasing

- Quantum Chemistry VQE (2014, U. of Bristol)
- Quantum Approximate Optimization Algo (2017, Rigetti)
- Quantum Machine Learning QCL (2018, Osaka U.)

World's first demonstration of quantum supremacy

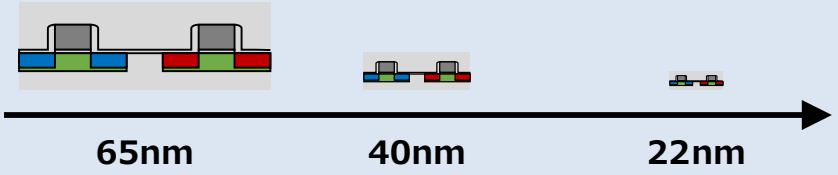
- Random Quantum Circuits Sampling (2019, Google)

Made with reference:
https://www.jst.go.jp/crds/pdf/2018/SP/CRDS-FY2018-SP-04.pdf

Our direction with silicon technology

- Si technology can not only reduce the size of qubits, but also integrate many qubits and many functional circuits on the same die.
- Take the pros of the integration to overcome the cons of small “silicon qubits.”

CONEVTIONAL: Reduce the size of qubits



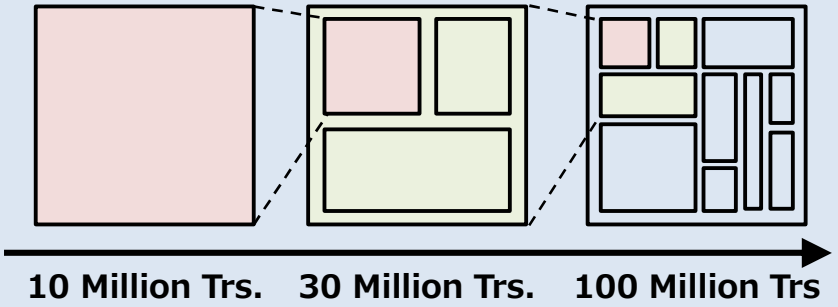
Pros

- ✓Have strong exchange interaction

Cons

- ✓Makes it difficult to control the qubits
- ✓Induces noises such as crosstalk

THIS PROJECT: Integrate many qubits and many functional circuits



Pros

- ✓Control the qubit precisely with control circuitry integrated on the same chip
- ✓Many qubits with uniform characteristics can be integrated.

Cons

- ✓Circuit integration causes heat generation

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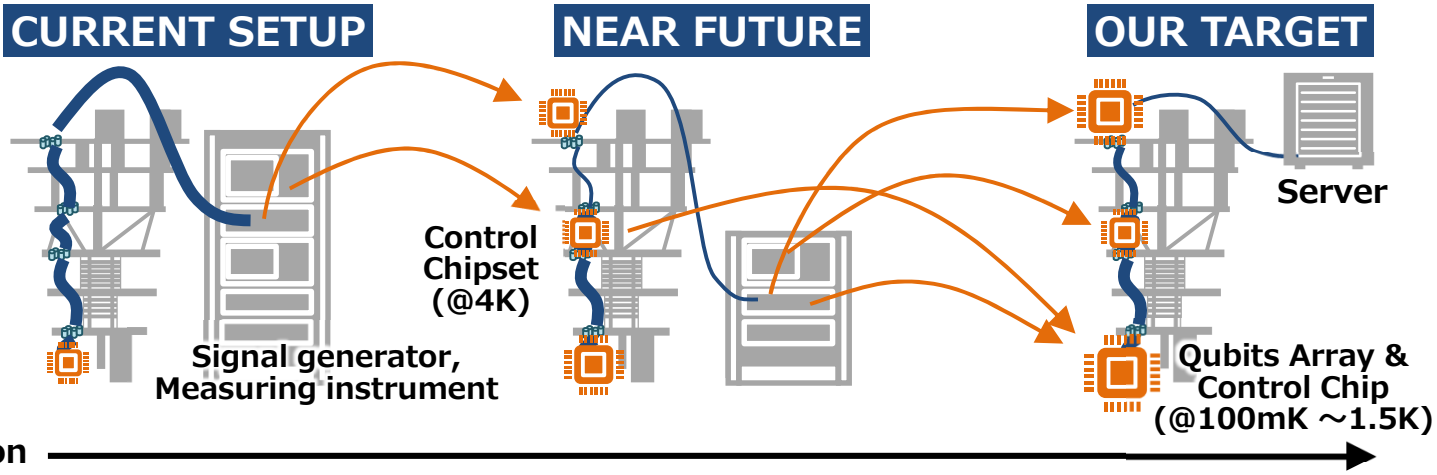


https://spectrum.ieee.org/tech-talk/semiconductors/design/google-team-builds-circuit-to-solve-one-of-quantum-computings-biggest-problems

Pros
- ✓Have strong exchange interaction

Cons
- ✓Makes it difficult to control the qubits
- ✓Induces noises such as crosstalk

Overcome

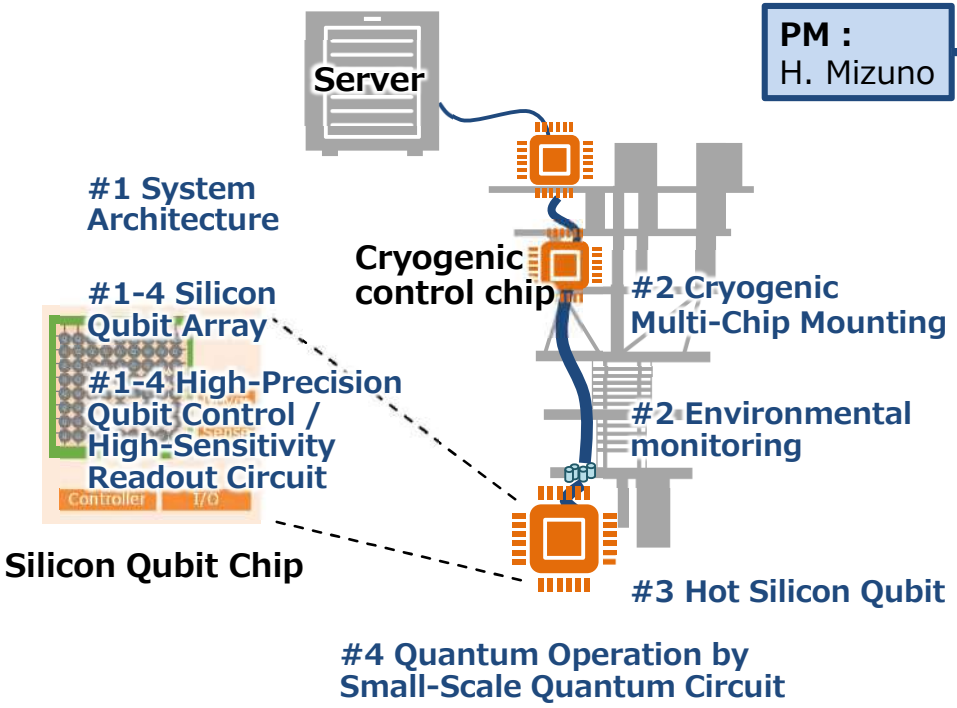
Pros
- ✓Control the qubit precisely with control circuitry on the same chip
- ✓Many qubits with uniform characteristics can be integrated

Cons
- ✓Integrated circuits generate heat

→ Hot silicon qubit, Environment Monitoring

Project R&D Structure

- Vertically integrate the development to maximize the power of silicon technology.
- QC development has shifted from the research phase to the development phase, but scientific innovations of qubit devices/physics and algorithms are still essential.



PM :
H. Mizuno

#1 Hitachi / H. Mizuno Group
Quantum Computing System

#2 Kobe U / M. Nagata Group
Cryogenic Multi-Chip Mounting System

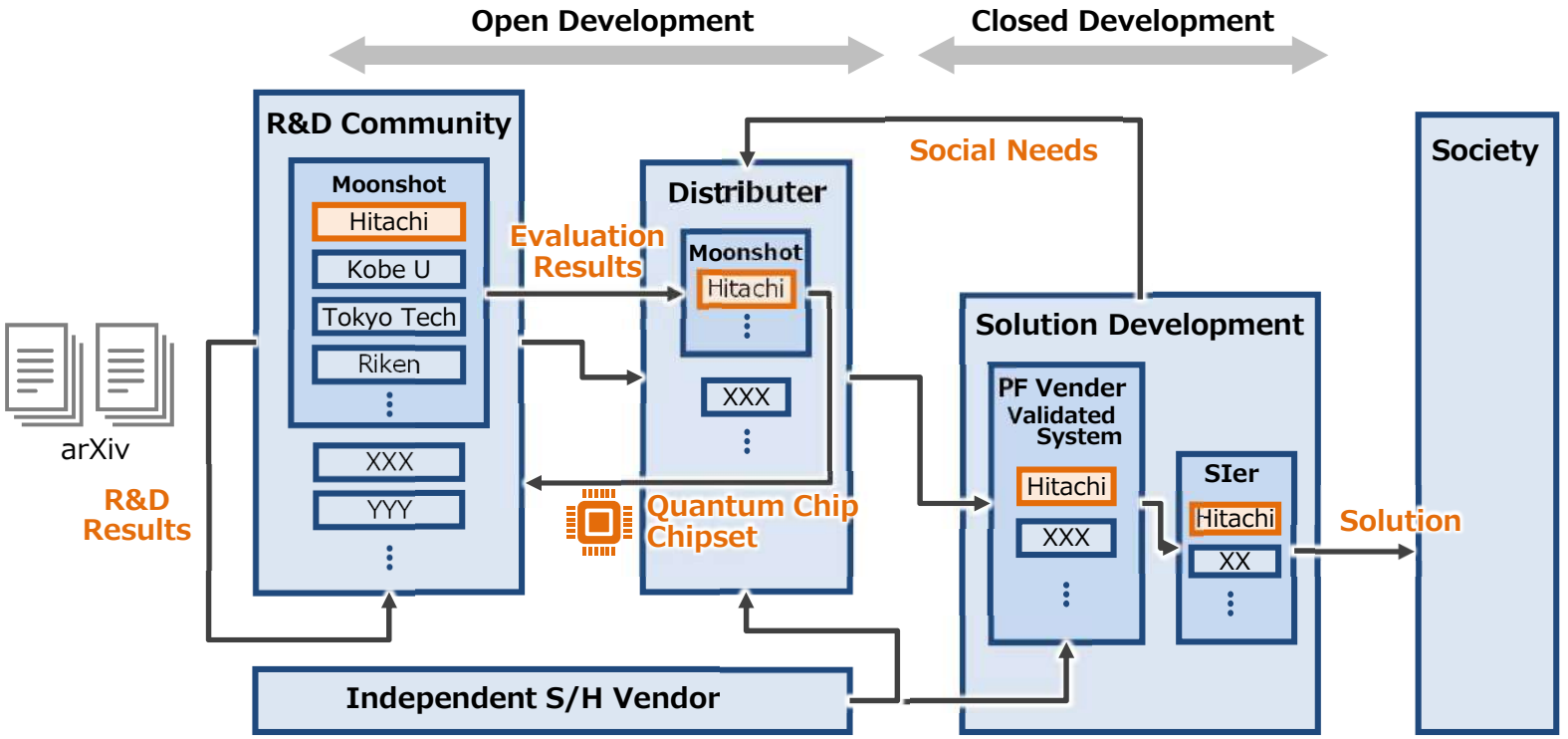
#3 Tokyo Tech / T. Kodera Group
Hot Silicon Qubit

#4 Riken / T. Nakajima Group
Quantum Operation by Small-Scale Quantum Circuit

Collaboration with Other Projects
- Solution for quantum error【**M. Koashi PM**】
- Quantum Network between Qubit Arrays 【**T. Yamamoto PM**】

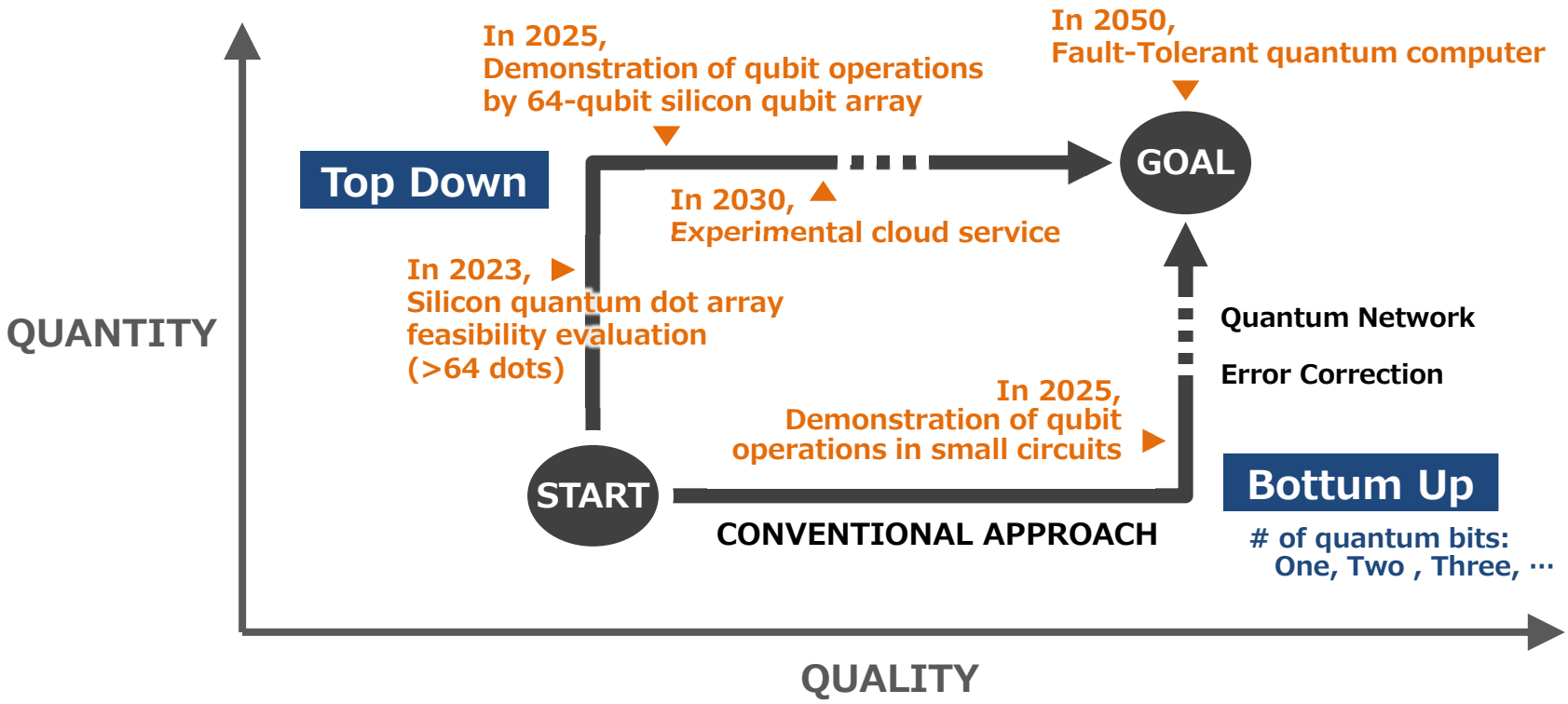
Open Development for Silicon Quantum Chip

- Build an open development system aiming at early development of silicon quantum chips by learning from the opensource software (OSS) method.



Scenarios and Milestones

- Early social implementation and goal achievement with the maximum usage of the power of silicon qubits



Summary

- Large-scale integration of qubits is the key to achieving fault-tolerant quantum computers.
- In addition to using silicon technology to optimize the silicon qubit structure and improve the accuracy of qubit operations, we use silicon to integrate many qubits uniformly (**2D qubit array**) and to integrate circuits to control the qubit on the same die (**QCMOS process**).
- To maximize the power of silicon technology, our project will develop several technologies such as **hot silicon qubits** and **environmental monitoring** for them.
- Our project built a collaborative system between academia and industry, we would also like to build an open development system for silicon qubit chips.

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