

# Feasibility Studies on Next-Generation Supercomputing Infrastructures: System Software and Library Research

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## Aim of the Project

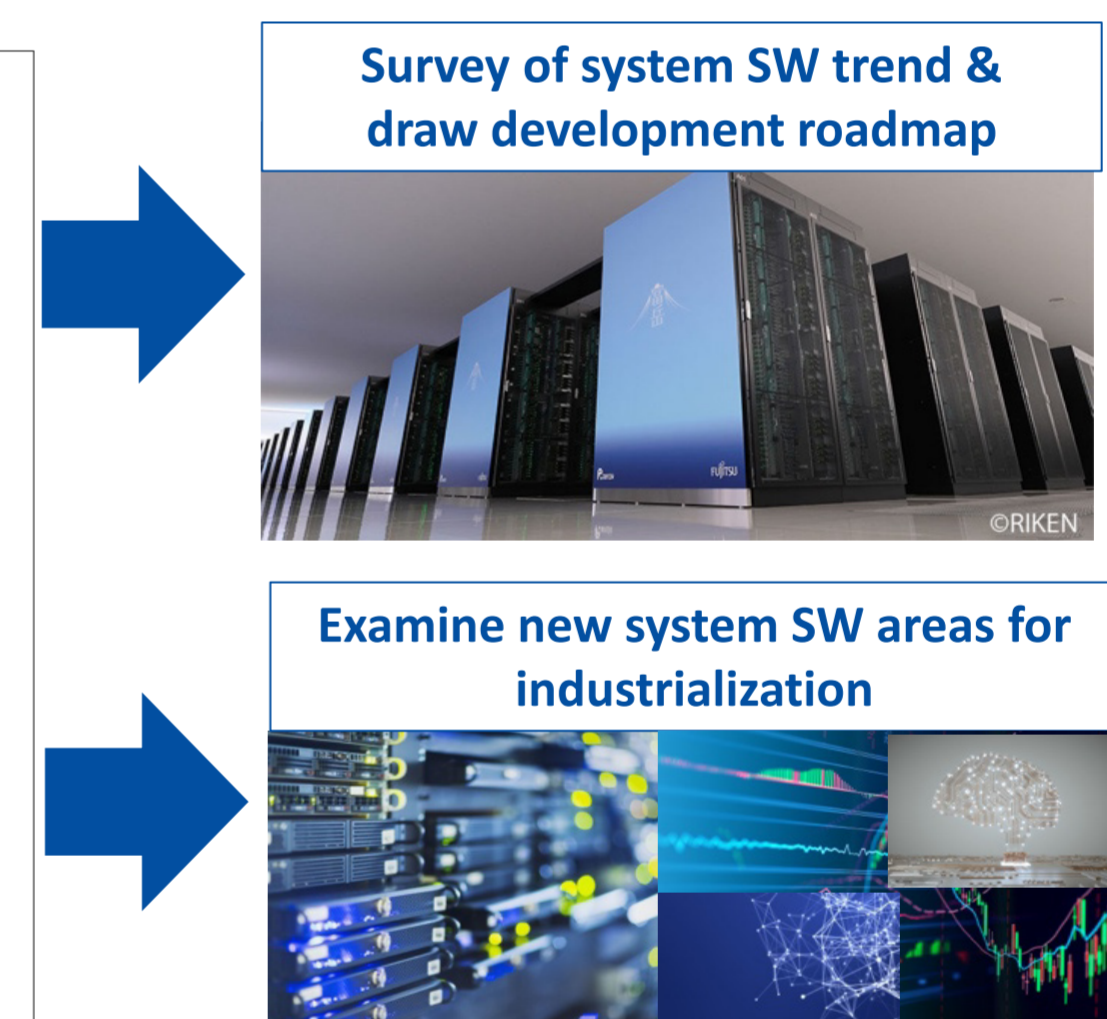
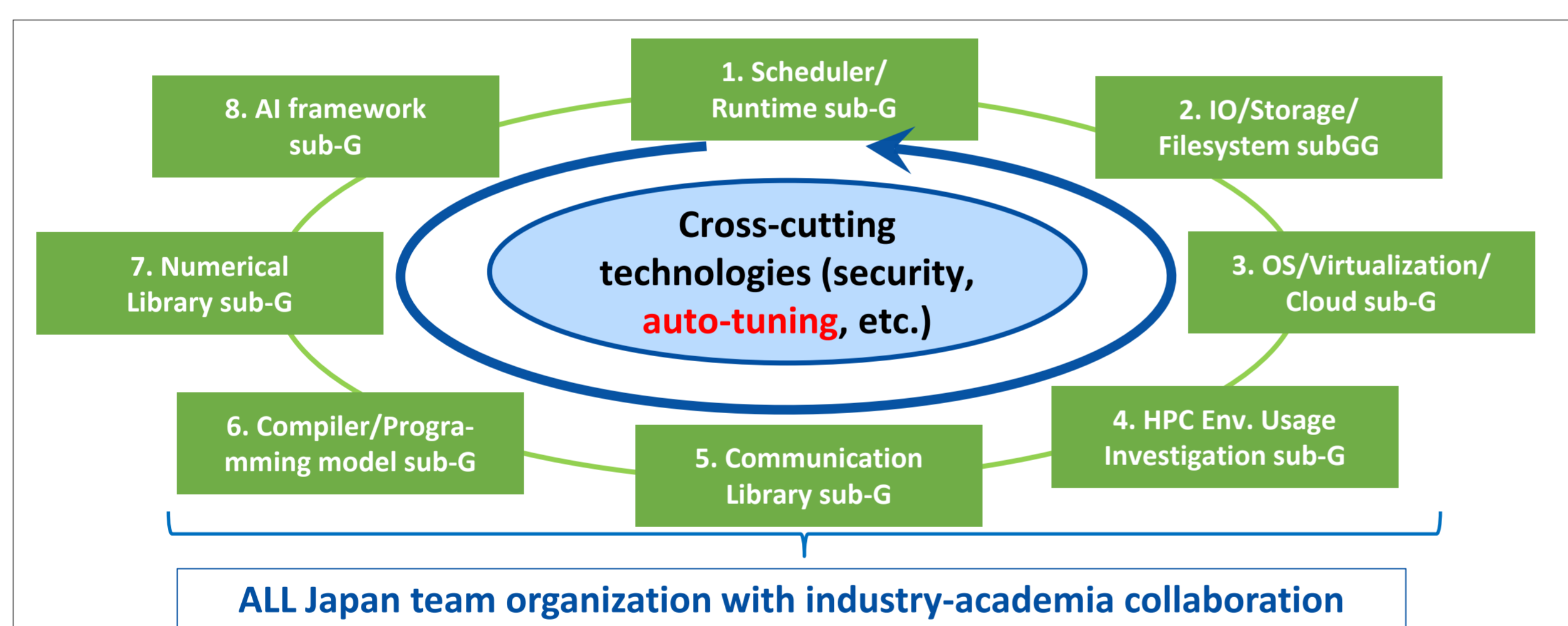
The next-generation computational infrastructure is expected to become a platform for realizing SDGs and Society 5.0 by **providing advanced digital twins** that will bring "Research DX" in the science. Aiming to realize a versatile computing infrastructure that can **execute entire workflow by making full use of wide range of computational methods, simulation techniques, and BigData** at scale, we conduct a holistic investigation on architecture, system software and library technologies through co-design with applications.

As a basic principle of system design, we **practice the "FLOPS to Byte" concept** from architecture development to algorithm or application design to **streamline data transfer and computation under power constraints**, while taking necessary computing accuracy into consideration. Under the **ALL JAPAN team composition**, we will investigate system configurations and elementary technologies which improve effective performance of the next-generation computing infrastructure.



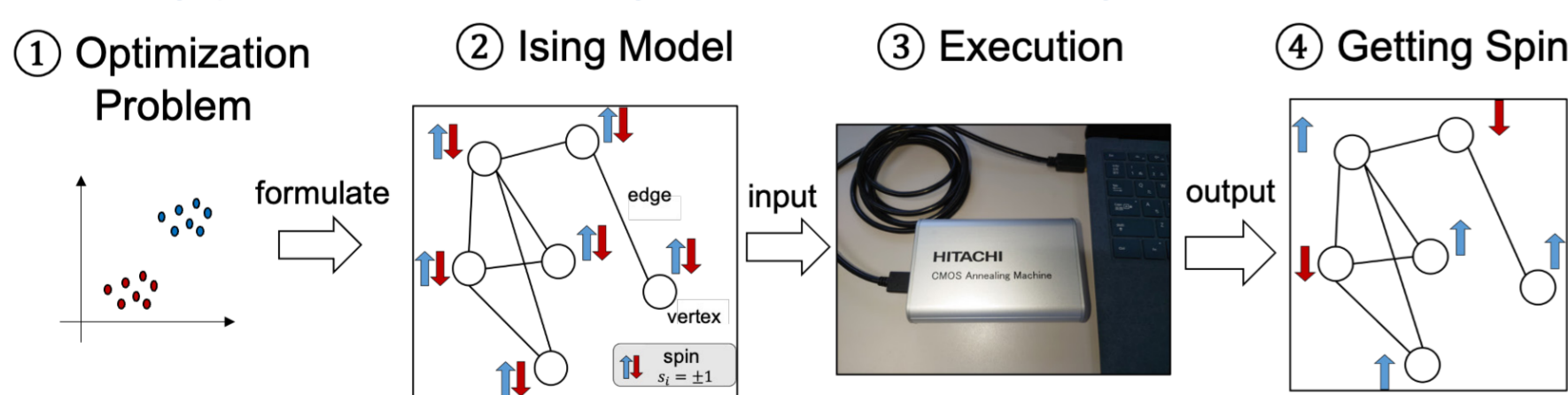
## System Software and Library Research

- Investigate technological trend of system software and draw R&D roadmap based on it
  - Holistic studies on 8 system SW areas, cross-cutting technologies (security, auto-tuning, etc.) and platforming
  - Prioritize SW / tools to develop domestically by considering usage on flagship and 1-tier machines, **development cost, proficiency of existing ecosystem**, and other factors
- Study new technological area in system software for industrialization
  - Investigate new areas of development to encourage use in a wide range of applications
  - **Providing a platformed digital twin environment for industrial use**, promotion of data utilization, fusion of machine learning & first-principles simulation, advanced large-scale real-time data processing, high security, etc.
- ALL JAPAN team organization with industry-academia collaboration
  - Expect future ripple effect on HPCI supercomputer centers



## Adaptation of Auto-tuning to Quantum-Inspired Annealing Machine

- Quantum-inspired computers are being developed.
  - CMOS Annealing Machine (Hitachi), Digital Annealer (Fujitsu), etc.
- Solving procedure using CMOS annealing machine.



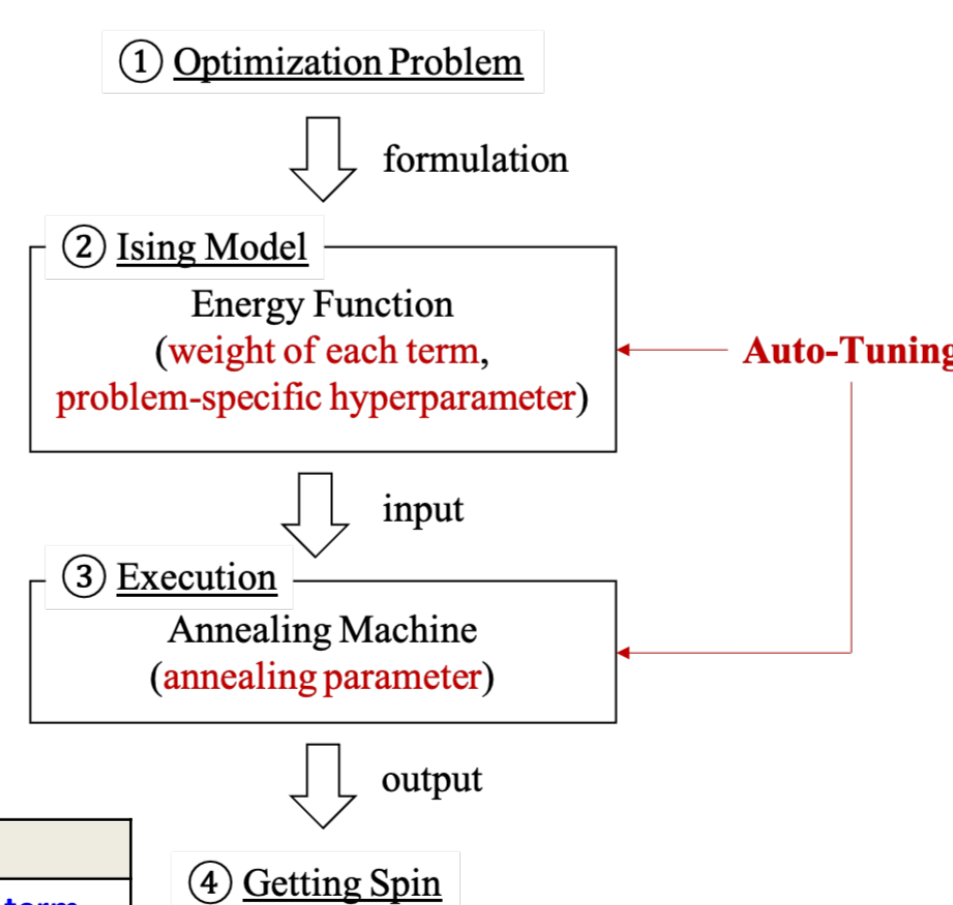
### Parameters to be tuned on CMOS Annealing Machine

QUBO formula

$$H = W_a \sum_{(u,v) \in E} (1 - x_u)(1 - x_v) + W_b \sum_{v \in V} x_v$$

| Parameters              | Overview                         |
|-------------------------|----------------------------------|
| $W_a$                   | Coefficient of constraint term   |
| $W_b$                   | Coefficient of cost term         |
| chain_strength          | Strength of chain                |
| temperature_num_steps   | Number of steps in annealing     |
| temperature_step_length | Length of steps in annealing     |
| temperature_initial     | Initial temperature in annealing |
| temperature_target      | Final temperature in annealing   |

### Procedure of Auto-tuning



### Results

#### Minimum Vertex Cover Problem

Find  $V'$ , which is the vertex covering set (where  $|V'|$  is the minimum, Graph  $G=(V,E)$ ,  $V' \subseteq V$ )

The optimal solution ratio [%] with default values

|         | $w_a$ | $w_b$ | chain_strength | Optimal solution ratio |
|---------|-------|-------|----------------|------------------------|
| $N = 3$ | 1.00  | 1.00  | 1.00           | 5%                     |

The optimal solution ratio [%] with auto-tuned settings

|         | $w_a$ | $w_b$ | chain_strength | Optimal solution ratio |
|---------|-------|-------|----------------|------------------------|
| $N = 3$ | 9.76  | 0.01  | 6.42           | 86%                    |