PD's Policy on the Calls for Project Managers of Moonshot Goal 6

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1. Overview of the R&D program aimed at achieving Moonshot Goal 6

Amid the growing belief that conventional computers are approaching their limits of progress, quantum computers are gaining attention for their ability to meet the exponentially increasing demand for diverse information processing. In order to solve diverse, complex and large-scale real-world problems efficiently with quantum computers, the key is to realize a fault-tolerant quantum computer (FTQC) that can perform computations accurately while correcting quantum errors. Moonshot Goal 6 aims to realize a large-scale FTQC that exceeds the capabilities of supercomputers by 2050 and promote research and development (R&D) that are relevant to achieve the goal.

2. Setting the program milestone

In order to realize large-scale quantum computers by 2050, I have set a milestone of achieving a medium-scale fault-tolerant quantum computer by 2040, which will enable useful calculations that are difficult to perform on supercomputers. The goal is to achieve a PoC for a quantum computer with small-scale or partial fault tolerance by 2030.

Full-scale participation of industry is essential for developing the fault-tolerant universal quantum computer system that Goal 6 aims to achieve. For this reason, I believe it is crucial that the PMs create a project that includes domestic companies from the beginning.

3. Objectives of this call

For Goal 6, I have driven R&D projects in three categories: 1) Quantum computer hardware, 2) Quantum communications, and 3) Fault-tolerance. To date, we have selected 12 PMs, and each has achieved research outcomes that align with or even surpass their original objectives.

On the other hand, since the project objectives were set in 2020, this field has progressed significantly worldwide, and the limitations of using NISQ (Noisy Intermediate-Scale Quantum Computer) have become noticeable. Recently, the development of quantum computers and quantum error correction research for FTQC have become a global trend. The 2030 milestone for this program was based on the 2020 global trend of NISQ development, but now it needs to be updated to the milestone aimed at FTQC. Additionally, while the R&D until 2025 has focused on core technologies, it is now essential to clarify the roadmap toward quantum computer system development and enhance the projects by integrating these technologies. Furthermore, addressing the duplications and conflicts in R&D among the projects within the program is crucial. In light of this, I have determined that a large-scale restructuring of the program is required for Japan to compete with the world by 2030.

Therefore, all 12 ongoing projects will be concluded by FY2025, and we will proceed

with the second half of the program under the newly established framework formulated through this call for proposals. I also want to effectively invest in R&D towards 2030 (and beyond) by reviewing our portfolio to focus on achieving our goals and making bold revisions aimed at financially supporting the large-scale integration of quantum computer system.

I anticipate seeing restructured projects with bold revisions that will produce results on par with the world's best. I hope that the plans will be able to utilize the facilities and research environments cultivated by the program and promote the integration of the core technologies developed under Goal 6. In addition to reviewing the milestones, one of the aims of this call is to encourage the voluntary restructuring of each project.

I also anticipate welcoming researchers who had been unable to join due to various reasons, such as not being able to devote their efforts because of prior engagements, as well as researchers from other fields such as computer science and computer architecture.

There are already high expectations for quantum computers, but it will likely take time to develop FTQC that can truly meet these aspirations. To achieve the R&D of FTQC, which is expected to require a large amount of funding and human resources by 2050, it is essential to continuously secure the understanding and support of companies and citizens. For this reason, I have added a new research theme of applications of FTQC. The project under this theme will work towards developing new applications that make use of the characteristics of quantum computers, while taking into account the specifications of the quantum computer systems being developed both within and outside the MS6 projects. Conversely, I believe that the project adopted under this new theme will clarify the specifications of the quantum computer that Goal 6 should ultimately develop. As the social implementation of the results of Goal 6 will be carried out through applications, the adopted projects will also address ELSI issues.

I will require all adopted projects, not just the project for application of FTQC, to actively engage in outreach activities that promote dialogue with society and disseminate accurate information.

When building the structure for each project, proposals that actively involve young researchers in a way that makes them visible while advancing the 2050 goals are desirable.

I recognize that international collaborative activities that increase Japan's presence on the world stage and strategically incorporating knowledge from overseas are one way to increase the value of the project. However, when collaborating with overseas partners, it is also necessary to take into account research security measures. In particular, when trying to get overseas companies involved, it is a prerequisite that the project will contribute to the national interest not only during the project period but also in the future, and in some cases, it may be necessary to restrict access to information even within the program and between projects during the exchange of ideas. In light of these risks, I believe it is important that the projects are open as possible, while closed as necessary. In some cases, it has taken over a year to coordinate contracts with overseas companies in the first half of the program, so when planning to involve overseas companies, please carefully consider the necessity, effectiveness and feasibility of doing so.

4. Research themes of the call

The outline and the budget of each project to be selected for this call are as follows.

Call theme	Estimated budget (including overheads)	Number of selections
(i) Quantum computer system	5 to 10 billion yen per project	0～5
(ii) Quantum bus and quantum communication network	3 to 5 billion yen	0～1
(iii) Quantum error correction and FTQC theory	0.5 to 1 billion yen	0～1
(iv) Quantum error correction system (classical part)	5 to 7 billion yen	0～1
(v) Applications	0.5 to 1 billion yen	0～1

・The budget listed above is only a guideline, so please propose the budget necessary by 2030.

・The budget will be decided based on the evaluation of the proposal.

・Including R&D items or PI candidates without clear roles or positions related to achieving the project's goals may undermine the credibility of the proposal, and may also be considered unsuitable from the perspective of the PM's management ability. Even if such a proposal is selected, significant revisions might be required.

・For the quantum computer system projects in (i), please note that if you plan to utilize the results of the error correction systems (classical part) in (iv) and/or quantum bus and quantum communication network in (ii), you must include a proposal with the necessary budget for that purpose. Specifically, the error correction system developed in (iv) will not be provided as a real machine to the project in (i). Furthermore, after adoption, it will be necessary to carefully agree on what and to what extent will be done between projects.

(i) Quantum computer system

・To develop a quantum computer system that can expand the number of physical qubits to the physical upper limit with an arrangement that is highly compatible with quantum error correction, while minimizing the physical size and quantum error rate.

・The milestone set for 2030 should be on a par with the world. Specific targets for the number of qubits and error rate must be clearly stated.

・The effectiveness of quantum error correction should be demonstrated at an early stage.

・Companies that will lead the R&D in the future must be incorporated into the project.

・There must be a PI in charge of system integration and a PI in charge of fault-tolerance experiments.

・The number of projects selected will be limited to at most one per each physical qubit system.

(ii) Quantum bus and quantum communication network

- Establish common infrastructure technology needed to realize a distributed large-scale quantum computer.
- As a cross-cutting measure, the project aims to provide technology by conducting R&D on the quantum bus and quantum communication network required by the quantum computer system in project (i). Priority should be given to implementing solutions that are highly necessary, effective, and can be realized early.

(iii) Quantum error correction and FTQC theory

- To research and develop the theory and software needed to realize a fault-tolerant universal quantum computer.
- As a cross-cutting measure, to develop a design method that can be applied to all of the quantum computer system projects in (i).

(iv) Quantum error correction system (classical part)

- To develop a classical information processing system that can perform large-scale, high-speed error syndrome analysis for quantum error correction.
- To develop a system that can achieve quantum error correction that makes 100 to 1000 logical qubits available for use in quantum algorithms, ensuring that it is scalable beyond that.
- As a cross-cutting measure, it must correspond to all of the quantum computer system projects in (i) that require (iv).

(v) Applications

- To research and develop applications for fault-tolerant quantum computers that solve problems that are difficult to address with supercomputers within a realistic timeframe or to ensure the required level of computational accuracy.
- Estimate the resources (number of logical qubits, number of logical quantum gates) required to run the application and to reduce the amount needed.
- Develop a method for developing FTQC applications.
- As FTQC is implemented in society through its applications and has a societal impact, it is essential to address ELSI.
- Applications targeted include those for quantum computers with partial fault tolerance, but exclude those for NISQ.