Moonshot International Symposium
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Plenary Session 1

The Management of the Moonshot and new Policy-making in STI

Management Paper

CONTENTS

PREAMBLE

The Council for Science, Technology and Innovation (CSTI) is the leading governmental organization for STI policies in Japan. The mission of the CSTI is to create a five-year Basic Plan for Science and Technology, and to give policy advice on STI to the government and Prime Minister's Office.

Based on the underlying 1995 Basic Law for Science and Technology, the CSTI created the first basic plan in 1996. Since then we have completed four plans for twenty years and are now in the 5th Basic Plan. This year, the intermediate year of the plan, we are now embarking on the amendment of the Basic Law and creating a new Basic Plan to be announced in 2021.

The CSTI started in 2001 as the Council for Science and Technology Policy (CSTP), modeled on the similar institution, the Office for Science and Technology Policy (OSTP) in the US. Over time, the CSTI's nature and characteristics have gradually transformed. One of biggest changes can be seen in the institutional title: in 2014 the CSTP became the CSTI by adding the word "innovation," which indicates greater focus on economic and social issues.

As the current Basic Plan declares as its mission transforming Japan into "the most innovation-friendly nation in the world," the Council has been very concerned about the way to transmit the scientific and engineering seeds to the innovative enterprises.

Naturally, the CSTI has been involved with "mission-oriented" and "High-Risk High-Impact" research and development such as FIRST and ImPACT as you see in the next section. The Moonshot R&D Program is the subsequent endeavor of these projects.

The Moonshot Program will be one of the most important symbolic policy pillars in the 6th Basic Plan for Science and Technology that the CSTI is now creating. Developing the Moonshot to experiment as a canvas for new STI policies, the CSTI will lead the intellectual challenge of creating a global model of STI policy to nurture "Disruptive Innovation" through government funding.

I. THE MOONSHOT: A NEW MISSION-ORIENTED R&D PROGRAM AND CSTI

The Moonshot Research and Development Program is the Japanese government's new emblematic R&D enterprise that the CSTI designates to organize Japan's state-of-the-art scientific and engineering technologies into more disruptive techno-social innovations.

Today, the world is faced with big transformations such as global warming and environmental disruption that are commonly understood but difficult to reach an agreement about the solution; expanding population and future scarcity of food that are seemingly not urgent but will seriously damage the wealth of the world; shrinking the boundary between human and non-human that has been accelerated by the advancement of AI technology; declining birthrate and aging society that are prevalent in most of the leading countries but no other country than Japan has experienced at the similar level of gravity; and so forth.

How can we solve these global challenges by "national" policies of science, technology and innovation (STI)? In what way do the technologically advanced countries go hand in hand to tackle them and open a prospect for the rosy future of the world? Is the conventional approach to STI policies enough and appropriate to create truly dynamic breakthroughs which will lead to the fundamental resolution of the problems?

To cope with such questions, many countries have promoted various high risk-taking approaches in STI policies. In other words, some specific forms of R&D programs are intentionally selected to seek more disruptive or radical innovations rather than incremental or cumulative investigations. For example, the German government has considered establishing an organization which focuses on High Impact Research Development. Similarly, the European Commission is now planning to implement "mission-oriented" research programs under the platform of Horizon Europe starting in 2021. In the United States, a pioneer in undertaking disruptive and audacious enterprises such as the Apollo Project and the War on Cancer, the National Science Foundation has been promoting the 10 Big Ideas program investing $30 million in each Idea.

Similarly, the Japanese government is launching our own "Moonshot R&D Program", setting ambitious and disruptive goals to address the social challenges we face, bringing together the wisdom of researchers from all over the world, and producing cutting-edge research results while making full use of basic research capabilities even as we allow for unexpected failures.

Upon the request of the CSTI, a "Visionary Council" of expert scholars has extensively advised the CSTI concerning the possible missions and goals that the Moonshot R&D Program should select. As you see in the Appendix for "Proposed Moonshot Goals" in the

Session 2, the Commission proposed 25 examples of goals and 13 visions grouped into 3 major areas: Leveraging the Aging Society; Saving the Planet and Our Civilization; and Exploring New Frontiers of Science and Technology.

Most of the proposed goals such as “Creating and deploying cyborg Technology to Augment Human Capability by 2050,” “Harmonization between Agriculture and Biodiversity,” “Elimination of Garbage on the Earth,” and “Creation of Digital Model of Entire Nerve system and Adjacent Systems” sound very adventurous and bold. It is important to point out that the visions and goals proposed by the Moonshot R&D Program are not stand-alone and will not be realized over a short amount of time, but often or usually will be accomplished together through long-term government funding for fundamental research.

II. INOVATIVE MANAGEMENT OF MOONSHOT R&D PROGRAM

(1) The Policy Dilemmas for Mission-oriented Research and Development

Though the Moonshot is a newly launching R&D program, its conceptual framework comes from reflecting upon the CSTI's past mission-oriented projects and programs. They are FIRST: Funding Program for World-Leading Innovative R&D on Science and Technology (2010-2013) and ImPACT (Impulsing Paradigm Change through Disruptive Technologies Program (2014-2019)).

Selecting and focusing on thirty targeted fields, FIRST was designed to promote leading-edge research and researchers in various fields and at different stages of progress from very basic to applied studies. Under the banner of "first priority given to researchers," it adopted a new evaluation system to encourage curiosity-driven research, and it allowed multi-year and very flexible usage of research money, all to better encourage long-term, innovative projects and researchers who could concentrate exclusively on their research.

The other mission-oriented program was ImPACT that attempted to incorporate promising technologies from inside and outside Japan and aimed to achieve higher R&D targets. Learning from America's R&D model under the Defense Advanced Research Projects (DARPA), ImPACT aimed to encourage challenging and bold research and high-risk, high-impact R&D, and to realize disruptive and expandable innovations.

In carrying out these mission-oriented programs, we had to face policy dilemmas that turned out to be very evocative in planning the Moonshot R&D Program. (a) Although successful in cultivating creative and ingenious research ideas, the FIRST was sometimes questioned as to how well it linked cutting-edged research with radical innovations. (b) On the other hand, the more mission-oriented the government's R&D projects were, the more they tended to hinder the free-minded and audacious imagination of researchers. (c) Although the ImPACT advocated high risk and high impact research as its slogan, too much emphasis on innovations sometimes made the project act as a simple bridge to private corporative R&D activities. (d) One dilemma was that the social problems we should tackle cannot be solved only by the force of science and technology, but also require social policies such as regulatory reform. (e) Another dilemma was that as the societal challenges we should tackle become more and more global, mission-oriented programs by one country is not enough to realize the final goals.

Briefly, in order to pursue disruptive and techno-social innovations, we need to adopt much more innovative management systems of research and development. The most important question here is : how best might the public money promote such mission-oriented programs including disruptive and risk-taking innovations?

(2) The Challenge for Government-Funded Disruptive Innovation

To use an economist's definition, disruptive innovation is innovation that creates a new market and value network and eventually disrupts existing ones, displacing established market-leading firms, products, and alliances. It tends to be a challenge with high risk and high return. In other words, there is one great success over many failures. The challenge, the "dilemma" for disruptive innovation is that current governmental research funding, which maintains accountability to tax payers, prefers to support stable research and development (R & D) that is expected to be 100% successful. Our challenge is to resolve this contradiction, to find ways to fund potentially risky but potentially high-reward disruptive innovation, through prudent policy management.

One way to promote seemingly contradictory "government-funded disruptive innovation" is to re-frame the innovation challenge, to see it not as an "uncertainty" but as a "portfolio risk," which would permit the government, like private companies, to make strategic, risk hedging decisions. How do we solve the contradiction between challenges to a Moonshot Goal that include one great success over many failures, and support of government-funded R&D that expects to be 100% stably successful?

(3) Here are Some Basic Principles of Management System: Design and Evaluation Methods through which this sort of "risk-hedging disruptive innovation" might happen

1) Create an R&D portfolio system as a package for one Moonshot Goal, that is, evaluate these various approaches as a single package, no evaluation for each individual approach. Ensuring a wide variety of challengers (promoting variety not only in approach, but also in age, gender, nationality etc.) increases the probability of success.

2) Evaluate each approach only in the context of the overall process for the Moonshot Goal. This makes it possible to overcome failure as an experience and instead use it as a seed for new challenges. Therefore, we must first of all develop an overall scenario and an overarching goal.

3) Create new evaluation standards to provide different values for each package. This would include an Advanced Data Sharing and Data Management system as you see in Section IV.

4) Establish consistency and integrity in global standards: Moonshot goals are often on a global scale, so international standards and fraud prevention procedures would be vital in safeguarding the integrity of both domestic and international R&D and to facilitate researchers' collaboration and data sharing.

5) It is important to advance innovation while evolving. Moonshot program shall open a project, such as millennium challenge, to young people with a vision to create the future in 50 year through science and technology.

6) Finally, we would need, simply, an expanded understanding of "success" – one that would satisfy taxpayer demands for accountability but also enable Moonshot challengers to overcome failure and continue innovating.

III. CONTENTS OF MANAGEMENT SYSTEM: ITS DESIGN AND EVALUATION METHODS

(1) Uncertainty and Risk of R&D and Government Funding

To begin with, it is necessary to reconfirm our underlying recognition as to the role of public funding in promoting disruptive innovations. This basic understanding leads to solving the dilemmas listed above.

Therefore, let us start by considering the two concepts of "uncertainty" and "risk" in carrying out the Moonshot R&D Program. Borrowing the conceptualization by Frank Night's monumental book, *Risk, Uncertainty, and Profit* (1921), we define "risk" as situations where success of the work or operation occurs with measurable probability; while on the other hand "uncertainty" applies to situations where the likelihood of success is indefinite or incalculable. It is very unlikely that private corporations can undertake "uncertain" business because of stakeholders' monitoring, but it is likely that they invest on R&D as long as its risk of failure is predictable, calculable and not too volatile.

Considering this definition, then, we insist that the role of government should be to financially support even projects of "uncertain or "high risk" so that its initial investment by public money stirs the private sector's successive investment in R&D. Therefore, it is the government' responsibility to promote high-risk enterprise like the Moonshot R&D Program.

In reality, however, the R&D of disruptive innovations is largely conducted by emerging companies like Google, Amazon, Facebook and others because the government's involvement is often difficult. Allocating public money to disruptive innovations often becomes controversial. Why so? It is mainly because tax-paying money is hampered by the very strict rules of the government accountability office, so that any government R&D tends to be risk-averse.

In promoting the Moonshot's government-supported disruptive innovation, we would like to share the following recognition and agreement about its management design to ensure accountability for the research program to financial authorities.

(2) A Moonshot Program as a Whole Package

Each Moonshot goal will be very ambitious, adventurous, and audacious. However, their very audacity brings with it certain challenges. For example, many R&D programs declare that their final goals will be realized by the 2030s, 2040s or even 2050s. What sort of

mechanism for accountability should be created for such a long-term program? How should we evaluate such programs -- that is, how can we define their interim vs their long term failure or success?

First of all, we would like to see each program as a whole package or assemblage of many elements of activities: different types of research, various operations of the works, diverse ways of disseminating research data, innovative methods for tracking the progress of research activities, cutting-edge approaches to problems, a new formation research team, cultivating subsequent collaboration with other actors, propagating additional private sector's involvement on each program, harvesting new startup companies, and so on.

We want to evaluate each program as a failure or a success by looking at a whole range of these activities, not simply whether the publicly named goal is realized or not. In the course of the program's progress, there may emerge unexpected discoveries or inventions which might differ from the initial goal. But it is important that the Program Directors (PDs) completely figure them out, exploit all their potential, and even evolve them to other aims and values. They should not be seen as mere byproducts but positive, exploitable unit potentials.

(3) Portfolio Approach to Program Management

Looking at each program as a whole package of many research elements means that we utilize a portfolio point of view. Since one goal of the Moonshot R&D Program is to incorporate a variety of research components and activities, the potentials of each element, their process and progress, team formations, their approaches to targets, features of research participants, etc. must be very various. The probability of success or failure turn out to vary, topic by topic, target by target. Thus, it is essential to evaluate the entire Moonshot program by seeing it as one orchestra of all research topics, elements and characteristics.

The more diversified the program components are, the smaller the total package risk will be, which is why a portfolio approach will be successful. One topic may start with a small fund due to its high-risk; another may be more intensively funded because of its greater chance at success. Overall, it is like a portfolio of stock market investment. If properly managed, a diversified stock portfolio does not rise or fall by the success of one or two stocks; rather, because investments are diverse, profits can be maximized and risk minimized.

In order to create multifaceted and portfolio approach to Moonshot program, the PDs must encourage a wide range of participation. Different types of researchers should be invited irrespective of gender, nationality, age. Female and foreign scholars should be recruited as Project Manager (PM), and even young researchers could hold responsible positions.

The funding allocations for which the funding agencies are responsible shall be consulted with an advisory committee comprised of the relevant ministries, in order to balance the investment of all programs.

(4) Science Integrity and Reciprocity in promoting international collaboration

In pursuing our program, then, the underlying norm must be freedom of inquiry, transparency of research, openness of research outcomes, and reciprocity of participating countries in this program. The international S&T community will collaborate in the Moonshot R&D Program to exchange ideas regarding state-of-the-art technologies. The funding agencies will establish concrete framework for the international cooperation initiative of Japan.

Meantime, our strict rules of research conduct prohibit Moonshot participants from doing misconduct, fraud and plagiarism in order to preserve scientific integrity. In this regard, we are willing to work together with countries and their institutions that are sharing common value and principles with Japan. They should include basic principles concerning 1) rules-based open market economy, 2) fair and equitable framework of intellectual property rights and 3) improvement of the economic and social well-being of citizens.

The Moonshot will achieve this through the PDs, who will monitor scientific integrity and rules of conduct based on the global standards. The whole program will be evaluated from whether they successfully supervise behaviors of allied researchers, safeguard the integrity of both domestic and international R&D, and thus encourage researchers' full engagement with international collaboration.

(5) Implementation System of Program and Program Directors' Responsibility

PD is responsible to make a strategy of portfolio, named "Program", consisting of a number of research projects. PD shall fully understands and coordinates overall program, and manage new evaluation axes, such as advanced research data management as described in chapter IV.

PD is obliged to have an integrated plan of the implementation of the program. It means that he should have final figure of the future society based on his relevant technology and

show his plan to consolidate necessary technologies and systems, including existing or developing technologies not in his program. To do so, PD has to have close contact and cooperation with stakeholders of his plan in the beginning, and if necessary, he will involve these entities in his program in an appropriate timing.

The PDs supervise the program like conductors of the R&D orchestra. In other words, the PD is entrusted with authority regarding program portfolio, management plans, evaluating the success or failure of research elements, and prioritizing research projects, etc. -- all in light of the status of program's progress.

Each PD is required to maximize research results by timely reviewing the Moonshot program portfolio, assessing the methodology and progress of each research team, and reporting the rationale for this management of the overall program to interested third parties like the funding agencies.

Another important responsibility for the PDs is to keep detailed records of each program's process and progress, disseminating the research data using the Research Data Repository that the Moonshot R&D Program will utilize, and establishing progress metrics for each research component. This data repository system will be explored in the next section.

Inevitably, some highly innovative, unexplored and difficult approaches will face unexpected failures. In such a case, the PDs must analyze the causes of these failures and distil from them the beneficial lessons that may assist future success in terms of research methodology and/or research agendas. Even when a research fails, the PDs must assess the impact it has on other programs, cultivate other forms of industry collaboration, how valuable the failed one for the society and so on. In a nutshell, whether it is successful or not depends on making full use of the research results. Ultimately, even a program's "failure" may contribute valuable research results or suggestions for future methodologies or partnerships; it is the PD's job to articulate and develop these connections.

(6) Importance of Discussion and Preparation of ELSI

Moonshot R&D Program will open up a new era. It is important to discuss and prepare ELSI (Ethical, Legal (Ethical, Legal and Social Implications), Social Implications), in advance. In addition, PDs and PMs have to take care of the future standardization of each and whole technology.
STI often causes major regulatory revisions when apply to society for safety and security operation. If there is any regulatory barriers or problems to implement the results of

program in the real world, PDs have to report fundamental idea of the reform of the future social system to the government of Japan.

IV. ADVANCED RESEARCH DATA MANAGEMENT

With expanding intellectual frontiers and creating innovation, individuals and organizations rarely produce all the knowledge for success. Thus, cloud computing and open sharing of research outputs is increasingly important, especially in the era of Big Data and digital transformations. What is needed, then, is a secure and systematic way to share research process and its results.

Moreover, the Moonshot takes this into account. We plan to provide a systematic methodology for assessing the whole Moonshot R&D package: marshaling research ideas, coordinating them into the collaborations with other researchers and outside stakeholders, and so on. We will achieve this through an advanced data management, which is closely related with the Open Science Framework that the EU and other countries are creating.

The Open Science Framework, the future platform to make highly advanced scientific knowledge transparent, is becoming a worldwide trend in scientific research. Encouraging scientists to share and make mutual use of research findings across research fields and national borders is increasing the possibilities of creating and disseminating knowledge and value outside of conventional frameworks.

In response to this, the CSTI is promoting research data management and utilization, and the NII (National Institute of Informatics) has created Japan's research data infrastructure system, "NII Research Data Cloud", with full-scale operation in 2020. We have made every effort to develop a research data infrastructure and to form policies and guidelines to storage, share and utilize research data on the cloud system.

For example, we will have in place by FY 2020 Guidelines for the national R&D agencies to formulate data policies. Another outcome is a guideline for universities and national R&D agencies to develop and operate the research data Repositories, which would store and publish research data in an appropriate manner and in an internationally trusted form.

In order to carry out the advanced data management in the Moonshot R&D Program, we will start new research data management by experimentally utilizing the NII Research Data Cloud and etc. We further expect to structure the environment for searching metadata out of accumulated research outcomes, and to cooperate with other countries and international bodies. The government of Japan plans this data infrastructure and environment as a data-management model for other publicly-funded research in this country.

In turn, this data management system will be a methodological instrument for enhancing the accountability mechanisms of the Moonshot R&D Program. All of the research data stored in this platform should be open only with researcher's consent. By utilizing this system, however, the PDs are able to grasp the whole assemble of research outputs and encourage researchers to collaborate with private firms. As a result, the government will manage the Moonshot R&D Program while strongly advocating for its importance and impact to the public.

CONCLUSION

All in all, the CSTI's Moonshot R&D Program is a "Moonshot for R&D," at the same time it is a "Moonshot for Policy-making in STI."

We are introducing a new management style in promoting disruptive innovations by means of government funding: comprehending the program as a whole package, taking a portfolio approach to program management, creating an evaluation system to accept unexpected failures, building a new view to science integrity and reciprocity, and launching a platform of data sharing and open science.

Every effort linked to initiating the Moonshot, and the experiences we gain from its development, will in turn become assets for the CSTI, and will provide a powerful impetus to create the next Basic Plan for Science, Technology and Innovation in 2021.