Creating technology for Computing Revolution for Society 5.0

1. Objective Name
   Creating technology for Computing Revolution for Society 5.0

2. Overview
   To achieve Society5.0, which is exemplified by autonomous driving, intelligent robots, smart factories, and other similar technologies, intelligent information processing must be performed on the vast quantities of data obtained from a wide variety of IoT devices in real time and with great efficiency via information processing systems that run the gamut from edge systems to large-scale systems. Conventional information processing technologies have pursued performance improvements by miniaturizing semiconductors, as symbolized by Moore’s Law, but are now encountering the limitations of this miniaturization. We can no longer depend on innovative developments in future information processing technologies by merely extending the conventional technologies.

   For this strategic objective, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) will promote the efficient research and development (R&D), aimed at establishing innovative foundational technologies for computing that are conducive to improving the efficiency of all manner of information systems. This will be performed by creating new computing technologies by developing architectures designed to realize their real-time and low-power consumption properties, as well as high-speed processing for vast quantities of data. This will also be achieved through interlinking and achieving the coordination between technical layers, such as algorithms and architecture that are not bound by conventional techniques, as well as developing security technologies and applications that harness these.

3. Achievement Objectives
   For this strategic objective, the aim is to create innovative foundational technologies for computing that overwhelmingly surpass the conventional performance with the focus on improving the efficiency of information systems as a whole through high-speed processing, low power consumption, and cost cutting. Specifically, MEXT aims to achieve the following:

   (1) Create new computing technologies that will result in a major transformation in information processing in a qualitative manner
   (2) Develop efficient computing technologies that interlink and achieve the coordination between technical layers such as algorithms and architecture

4. Future Societal Vision When Promoting Research
   By achieving the items listed in “3. Achievement Objectives,” MEXT will contribute to achieving the type of society listed below by enabling an efficient undertaking of the appropriate information processing techniques for computing systems as a whole. This includes efficiently obtaining and analyzing information from various different sensors, real-time recognition, and decision-making on the edge side according to the circumstances and comparing this with and analyzing it against other accumulated data on the cloud side.

   • Society5.0 that consists of smart robots, smart factories, autonomous driving, IoT, and other technologies that harness sophisticated information processing.
   • A society where labor shortages resulting from the declining birthrate and population aging can be resolved; nursing care and support for the independence of the elderly and disabled can be provided; a secure, safe, and convenient means of transportation can be provided; the efficiency in manufacturing can be increased; social infrastructure can be efficiently preserved; security can be enhanced; privacy is ensured, and so forth.

5. Specific Research Examples
   (1) Create new computing technologies that will result in a major transformation in information processing in a qualitative manner
• R&D on new architectures designed to dramatically enhance the conventional performance by harnessing deep-learning algorithms, wired logic architecture, and other technologies with a focus on their real-time and low-power consumption properties.
• R&D on new architectures to result in technologies such as quantum computers, optical computers, and neuromorphic and brainmorphic computing with the focus on the high-speed processing of vast quantities of data.

(2) Develop efficient computing technologies that interlink and achieve the coordination between technical layers such as algorithms and architecture
• R&D for achieving dramatic improvements in performance via optimal combinations of algorithms, architecture, and hardware that utilize technologies from the field of computing (automatic control, diagnostics/prediction, distributed learning, etc.) with the focus on their implementation throughout society
• R&D for security technologies to secure the reliability of the vast quantities of data obtained from IoT devices by interlinking algorithms and architecture
• R&D on languages, compilers, and so forth for efficiently harnessing quantum computers by interlinking algorithms and architecture, as well as R&D on applications for efficiently harnessing neuromorphic AI

6. Research Trends in Japan and Overseas
(Trends in Japan)
In recent years, attention has been focused on research activities for computing technologies related to AI and deep learning. In 2016, the University of Tokyo initiated the R&D on brainmorphic AI technology, while the National Institute of Advanced Industrial Science and Technology (AIST) began developing a large-scale, power-saving cloud infrastructure for artificially intelligent processing equipped with 130PFLOPS of deep-learning computing power. In addition, progress is being made on the development of quantum annealing technology, such as through the Advanced Information Society Infrastructure Linking Quantum Artificial Brains in Quantum Network (iM Pact) Program, Hitachi Ltd.’s CMOS annealing chip, and Fujitsu’s digital annealer. Development is also underway on quantum computer technology using the superconductive quantum bits from the ERATO Nakamura Macroscopic Quantum Machine Project. Plans are underway for the Innovation Promotion Project for Accelerating the Development of AI Chips by the Ministry of Economy, Trade, and Industry (METI) in FY2018. As all of these consist of R&D specializing in algorithm, software, and device areas, we have not yet reached the point of research focusing primarily on the architecture area. As such, it will be extremely important to promote research in this area, which is tangentially connected to hardware and software technologies.

(Overseas Trends)
In the United States, DARPA’s SyNAPSE program has been making progress in developing neuromorphic chips since 2008, prior to the emergence of the von Neumann bottleneck problem; further, in 2016, IBM announced the TrueNorth. Since the launch of the Rebooting Computing Initiative by IEEE, Google has embarked upon the development of the TPU, a deep-learning accelerator chip, while NVIDIA, Toyota Motor Corporation, and others are engaged in a cooperative undertaking to develop an AI-equipped chip for autonomous driving. In addition, DARPA has launched HIVE, a research program specializing in graph analysis. These are just a few examples of how the US companies and others are investing in and jump starting the R&D in this field. In Europe, progress is underway on plans to set up 50PFLOPS of supercomputing capacity through the Human Brain Project, while the R&D on exascale technology is performed via Horizon 2020 as one of the policies of the European Commission. In China, initiatives are currently underway for a 100PFLOPS super computer system (Sunway TaiHuLight) via the country’s 13th five-year plan.

As indicated above, new initiatives for computing are gaining momentum from pragmatic areas such as GPUs and FPGAs to challenging research fields such as neuromorphic and quantum computing through the US companies and national policies.
7. Details of the Examinations
The examinations were conducted as follows based on the Policy for Formulating Strategic Objectives (approved by the Expert Panel on Strategic Basic Research, Council for Science, Technology, and Innovation on July 8, 2015).

(Drafting analytical materials related to research trends in Japan and overseas via scientometrical techniques through the use of the Grants-in-Aid for Scientific Research Database, and so forth)
Analytical materials related to research trends in Japan and overseas were drafted using scientometrical techniques such as the analyses of co-citation relations and direct-citation relations for research papers via the Grants-in-Aid for Scientific Research Database.

(Conducting questionnaires on experts through using analytical materials and drafting research trends that merit attention)
Questionnaires related to research trends that merit attention in the future were conducted using the analytical materials that were drafted. These questionnaires were administered to the sectoral units of the Center for Research and Development Strategy, Japan Science and Technology Agency (JST), the program directors, and others at the Japan Agency for Medical Research and Development, and the experts taking part in the expert network of the Science and Technology Foresight Center, National Institute of Science and Technology Policy. Thereafter, the results of the questionnaires were analyzed and “Creating Core Technologies to Underpin Society5.0 via Innovative Computing” was designated as a research trend that merits attention.

(Hosting workshops and drafting strategic objectives)
Workshops have been held by assembling experts from industry and academia related to the topic of “Creating Core Technologies to Underpin Society5.0 via Innovative Computing,” which is a research trend that merits attention. At these workshops, discussions were held on topics such as trends in Japan and overseas that merit particular attention, the social and economic impacts that advances in research and technical development could have, visions for a future society in which the results of this can be achieved, and objectives that must be achieved during the research phase. Based on the discussions at the workshops, the strategic objectives were drafted.

(Other)
- A CRDS symposium entitled, “Technology Innovation Toward IoT/Al Age: Defining Innovations for an Era of Revolutionary Change” was held in March 2017, where discussions were held on the need for initiatives geared toward substantially improving computing performance.
- Since April 2017, survey activities into innovative computing have begun within the CRDS. On July 26, 2017, an R&D strategy review committee on innovative computing was held, where discussions were held on the R&D fields that should be addressed in the future as well as the structures for promoting this.
- A CRDS workshop entitled, “Domain-specific Computing: A New Orientation for the Evolution of Computing” was held on November 29, 2017. At the workshop, discussions were held on topics such as the situation in Japan and overseas, expectations from industry, and approaches to R&D.

8. Related Mentions Found in Texts Approved by the Cabinet, etc.
5th Science and Technology Basic Plan (approved by the Cabinet on January 22, 2016)
Chapter 2 (3) <2> i)
- Device technology: technology that enables the high-speed, real-time processing of large amounts of data with low power consumption
- Edge computing: technology that enables increasing speed and diversification of real-time processing at the actual system location, which is necessary for increasing the functionality of IoT
Comprehensive Strategy on Science, Technology, and Innovation for 2017 (approved by the Cabinet on June 2, 2017)

Chapter 2 (2) [A] <2> i)

- Device technologies: It will be important to develop technologies for achieving high speeds and real-time processing for large volumes of data in ultra-compact forms with ultra-low power consumption.
- Edge computing: With the focus on speeding up real-time processing, promoting the construction of distributed processing technologies and building an architecture that considers the guarantee of secured gateways and other terminating units (or their lack thereof) will be important.

Chapter 2 (2) [B] <2> i)

- Information processing technologies: The development of component technologies such as 3D-integrated chips and quantum devices and architecture will be crucial to the realization of high-speed and large-scale information processing.

Chapter 2 (2) [C] <2> i)

- R&D will be promoted on edge computing that is designed to process vast quantities of data in real time, network technologies such as virtualization and processor optimization, and big data analysis technologies for extracting knowledge and value from data with great speed and precision.

9. Other

One example of a policy related to this strategic objective is MEXT’s Innovation Promotion Project for Accelerating the Development of AI Chips that is scheduled to begin in FY2018. This project aims for the early practical implementation of projects related to AI chips that allow for an efficient, high-speed processing through short to medium-term objectives, as well as obtaining the design tools for this. With this strategic objective, MEXT will develop foundational technologies that can contribute to the industry in the future in the form of R&D focused further than a medium- to long-term perspective. Additionally, initiatives for the research on algorithms, software for machine learning, and deep learning from MEXT’s Advanced Integrated Intelligence Platform Project (AIP Project; launched in FY2016) are complementary with this objective. Consequently, they must be organically promoted via a mutual coordination.

In terms of international strategy, it is important that countries aim to further improve computing efficiency by interlinking and achieving the coordination between various different technologies. This is to be performed by combining together applications and systems for which concentrated investments are already being made in the R&D by countries such as the United States, China, Taiwan, and the United Kingdom, together with the new technologies that are the aim of this strategic objective (circuit architecture, etc.).