# Strategic Proposal Catalog (2004-2015)

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Center for Research and Development Strategy
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# 1. Proposal for Issue-driven Research and Development III Promoting Life Course Health-care -Importance of Preemptive Medicine in pregnancy to childhood-【Executive summary in English】

Japan is experiencing rapid progress in the aging of the population ahead of the rest of the world, and the total population is considered to significantly decrease in the future especially for the young working age group. Additionally, medical and nursing care costs are considered to further increase in the future due to the advancement of medical techniques and increased demand for medical and health care. It is predicted that these issues will result in slowdown in the economic growth potential due to reduced domestic demands, reduction in the domestic production capability due to a decreasing working population, and failure of the medical and nursing care system, posing an extremely severe and difficult future for Japan. There are various factors intricately involved with the said issues. However, it should be possible to change the future of Japan by continuously promoting appropriate mid-to-long term remedial measures from early stages. CRDS has considered possible solutions by means of science and technology from the perspective of human health, in order to identify effective measures to counter these difficult issues.

First, CRDS specified three social expectations related to human health, namely, 1) realization of healthy longevity from the viewpoint of the nation, 2) ensured continuation of social security systems (e.g., optimization of medical and nursing care costs) from the viewpoint of the government, and 3) activation of medical and healthcare industry from the viewpoint of the industry. CRDS concluded that science and technology that satisfy these expectations and have the maximum impact on each social expectation are strongly required. In order to identify the specific direction of science and technology, CRDS conducted numerous literature reviews, overseas on-site investigations, opinion exchanges with experts, discussions at workshops, and so on. CRDS then conducted consideration on R&D strategy that needs to be promoted by overlooking the medical service provision and medical techniques for each health phase, the main health status and disease for each age group, the main relevant science and technology measures in
Japan, and so on.

Diseases that may cause significant reduction in QOL of people and cause a large social burden in the future have become a major concern in both developed and developing countries through the world. Examples of such diseases are cardio-metabolic diseases, chronic obstructive pulmonary disease (COPD), mental disorders, dementia,

and cancers. Appropriate measures against such diseases are in strong demand.
It has been known that these diseases break out as a result of gradual accumulation of disease risk factors through long-term interactions between genetic predisposition and environmental factors. It is considered that diseases that develop through such process are difficult to cure completely after onset and it is more efficient to intervene at early stages. For that reason, in FY2010, CRDS proposed the importance of a new healthcare and medical concept called preemptive medicine. Preemptive medicine is a medical method that identifies high risk groups through low-cost and highly accurate onset prediction techniques. Its aim is to protect the health of the nation through application of low-cost and effective preventive intervention techniques and to significantly reduce medical costs etc. by drastically reducing the number of progressors. It also aims at acquisition of foreign currencies through overseas expansion of preemptive medicine developed by Japan. Therefore, preemptive medicine satisfies all three social expectations stated above simultaneously. In late years scientific findings related to preemptive medicine have rapidly accumulated, and CRDS conducted consideration on R&D strategies taking into account their latest trend and on the measures for social implementation.

The onset period of chronic diseases subject to preemptive medicine varies depending on the disease (e.g., diabetes, Alzheimer dementia, cancer). Therefore, accumulation of disease risk factors may also exhibit various time dependencies related to the disease. In order to realize highly efficient and effective preemptive medicine, establishment of highly accurate disease risk assessment techniques as well as risk-specific preventive intervention techniques is strongly required through comprehensive identification of disease risk factors (i.e. what kinds of risk factors exist at what time and period of human life and at what strength) and time-serial analysis of the factors.

Regarding the time and period that preemptive medicine needs to focus on, important findings have become available recently. There are various reports (e.g., birth cohort studies conducted for decades in Europe and so on) indicating strong associations between environmental factors during the fetal period and infancy and obesity, cardio-metabolic diseases (e.g., diabetes, cardiovascular diseases), developmental disorders, mental disorders, and so on. All these diseases are considered to become an increasingly serious issue in Japan and the rest of the world in the future, and this is a highly important finding.

The above finding has a major significance in envisaging the ideal future healthcare and medical services. For instance, obesity and cardio-metabolic diseases are considered to develop over a long period of time, and conventional treatment methods have provided care mainly for healthy-looking middle-aged and elderly people. The above finding, however, indicates the importance of care from a far earlier time of life, even as far back as to the fetal period and infancy. Therefore, in order to efficiently and effectively promote preemptive medicine and assuredly satisfy social expectations, it is important to promote preemptive medicine throughout a lifetime.

Representative risk factors identified by cohort studies in Europe include undernutrition of pregnant women and low birth weight. Japanese women are relatively lean compared to those in other developed countries and the rate of low birth weight infants is high supported by the medical concept existing in Japan, have a small baby and raise to grow big. These facts indicate Japanese children are born with high disease risks, and it can be said that strategic action against these facts is an urgent task. Additionally, genetic predisposition of Japanese people is different that of western people, and environmental factors, medical services, social environment, etc. in Japan are different from those in western countries. For that reason, findings obtained in Europe may not be directly applicable to Japanese people, and establishment of scientific evidence targeting Japanese people is urgently required.

Childhood that comes after infancy is also a period where major physical development takes place, and it is considered that many disease risk factors accumulate during childhood due to the external environment. Childhood also allows for application of a wider variety of preventive intervention techniques (e.g., health education), and childhood is considered to be an important period to focus on in addition to the fetal period and infancy.

Currently, measures involved with preemptive medicine are gradually put into practice in Japan. While the number of measures that apply to the period from the fetal period to childhood is small, establishment of epidemiology bases required to conduct such studies is in progress. An environment that significantly accelerates research in the relevant fields in the future is gradually forming. Therefore, the present proposal addresses preemptive medicine promotion strategies focusing on the period from the fetal period to childhood.

CRDS conducted considerations on specific R&D strategies based on the factors above. CRDS came to a conclusion that it is important to carry out measures that 1) identify associations between the environmental factors during the period from the fetal period to childhood and onset of diseases at a later time, 2) elucidate the background mechanisms, 3) establish preemptive medicine techniques based on the basic findings, and 4) promote social implementation taking into account the ethical, legal and social implications (ELSI) and costs.

■ Specific R&D Tasks and Promotion Measures

The themes that need to be promoted in the future are roughly classified into the three categories listed below. The important items common to all three themes include: specification of core institutions and organizations that supervise the whole project from a mid-to-long term viewpoint; acquisition of human resources and development of the next generation; and appropriate activities in the perspective of ELSI.

● Establishment, operation and utilization of epidemiology bases

Integration (formation of consortium) of existing birth cohort, relevant biobank and so on shall be promoted in order to establish an environment that facilitates access to the data by researchers. Regarding important data items which are unable to be obtained by existing epidemiology bases, establishment of new epidemiology bases shall be planned based on thorough discussions (including measures to ensure mid-to-long term funding) and are to be commenced at the optimal time. The value of epidemiology information bases drastically increases through as-available introduction of latest findings and techniques from life sciences, measurement and analysis techniques, big data studies, and so on.

● Promotion of basic and fundamental life science studies

Epigenetic studies using model animals and human samples (placentas, umbilical cord blood, blood of pregnant women, and other biological samples), nutritional science studies, disease studies, and behavior science studies shall be promoted. Associations between the environmental factors during the period from the fetal period to childhood and related diseases and epigenetic transitions shall be elucidated. The importance of dietary habit (nutrition) is considered to be high among environmental factors, and nutrients with larger impacts shall be identified in detail. Additionally, biomarker discovery and a search for intervention methods for the period from the fetal period to childhood shall be conducted by making the best use of findings mainly obtained in disease studies for adults. Associations between various activities (e.g., sleep) and disease onset shall be clarified through promotion of behavior science studies on human fetuses and infants. Measurement techniques are essential for promotion of these scientific studies, and fetal measurement and analysis technique studies (as well as infant and child measurement and analysis technique studies) shall be promoted where a major breakthrough is expectant.

● Promotion of R&D towards social implementation and impact assessment involved with implementation

A package (disease risk assessment and intervention model) necessary for social implementation of preemptive medicine shall be established for each disease by collecting, managing and analyzing in detail the big data obtained through promotion of epidemiological studies and life science studies. Impact on the health, economy and society shall be quantitatively assessed in order to achieve maximum impact for the minimum implementation costs (measurement and analysis items).

In studies using prospective birth cohorts, the timing of obtaining achievements may vary depending on the onset age of the disease. For instance, studies on developmental disorders are expected to produce major outcomes in a few years, while studies on lifestyle-related diseases may require approximately 30-50 years or more to obtain meaningful outcomes and thus mid-to-long term activities are essential. Meanwhile, integrated analysis of various existing cohort and data groups obtained through governmental measures as well as studies using model animals and human samples are expected to produce a certain level of outcome in a relatively short period of time. It is important to continue producing various outcomes in a short-, medium- and long-term basis through strategic promotion of these studies and to continue promoting social implementation of preemptive medicine at the same time.

## 2. Proposal for Issue-driven Research and Development II Research on integrated social infrastructure management system toward the realization of a tough and sustainable society【Executive summary in English】

■ Position of this proposal

This strategic proposal maintains that Japan should strategically implement the fundamental research of *integrated social infrastructure management system* and the research and development of *science and technology of maintenance* as the effort of an entire nation aiming to find a fundamental solution to various problems associated with social infrastructures and to realize a robust and sustainable society.

Since Japan has already accumulated large amount of infrastructure, costs of the infrastructures such as maintenance, management, repair, and reinforcement are rapidly increasing, and accidents and defects caused by age-based deterioration are frequently occurring. Although there are many efforts of the industry, government, or academia to address critical issues, they are far from engaging in sufficient fundamental research and development of the foundation for efficient and effective maintenance of these social infrastructures.

Thus, this proposal uses a mid- to long-term perspective and focuses on suggesting research and development that improve methods for enabling the maintenance and upkeep of currently installed infrastructures spending the smallest social cost possible. This proposal thereby aims to build a robust and sustainable society while ensuring international competitiveness of Japan for the future.

■ Recognition of basic problems

Targeted social infrastructures here include public facilities for providing services such as transportation, distribution, public welfare, and information and communication as necessary for improving the welfare of the citizens and economic development. The basic point of management for minimizing the lifecycle cost of infrastructures is to properly identify conditions and functions of infrastructures and forecast future conditions and remaining service lives, and implement maintenance, management, repair, and renewal of infrastructures at proper timing by giving priorities to them based on the forecast. It is necessary to shift from evaluations and decisions of maintenance, management, and renewal that used to be often dependent on experiences and knowhow of veteran engineers to scientific processes based on data.

The development of a truly robust and sustainable society requires comprehensive management of lifecycles by breaking the boundary of conventional social infrastructure management based on the cooperation and fusion with different types of facilities and systems. This requires many new theories and achievements of research and development and a much more ambitious and larger social agreement among industry, government, academia, and the public sector than the previous most cross-sectoral program such as a Cross-ministerial Strategic Innovation Promotion Program (SIP) of the Cabinet Office, Government of Japan.

Meanwhile, maintenance is often affected by various materials and structures of targeted infrastructures and peculiarity and uniqueness of functions and performances expected in targeted infrastructures. Thus, maintenance cannot be easily generalized or standardized as universal theories and methods. Still, efficient and reasonable implementation of technological development and education in this field are necessary, considering the massive amount of currently installed infrastructures which will require maintenance in the future and an enormous variety of types and structures of these infrastructures. That is, it is necessary to establish maintenance engineering for social infrastructures based on experiences and theories and the science of maintenance with comprehensive targets by finding common theories to individual technologies and organizing them into systems.

■ Overview of this proposal

Design systems and methodology of maintenance for reinforcing social infrastructures and making them sustainable cannot be achieved in a short period. Yet, we need to make efficient efforts to realize them. This strategic proposal analyzes and makes suggestions for research and development strategies as the first step of the milestone leading to the systematization of more innovative maintenance methodologies.

One example of problems in science and technology of maintenance is that currently there is no system for identifying the conditions of infrastructures and making rational decisions concerning costs and priorities of repairs to be conducted or theories that assist such processes. The science of maintenance is expected to become useful for developing advanced technologies for identifying proper timing and method of repairs, but it is still just an ideal at this point. The second best option is an economical and reasonable approach that is a systematic effort supported by technologies and data.

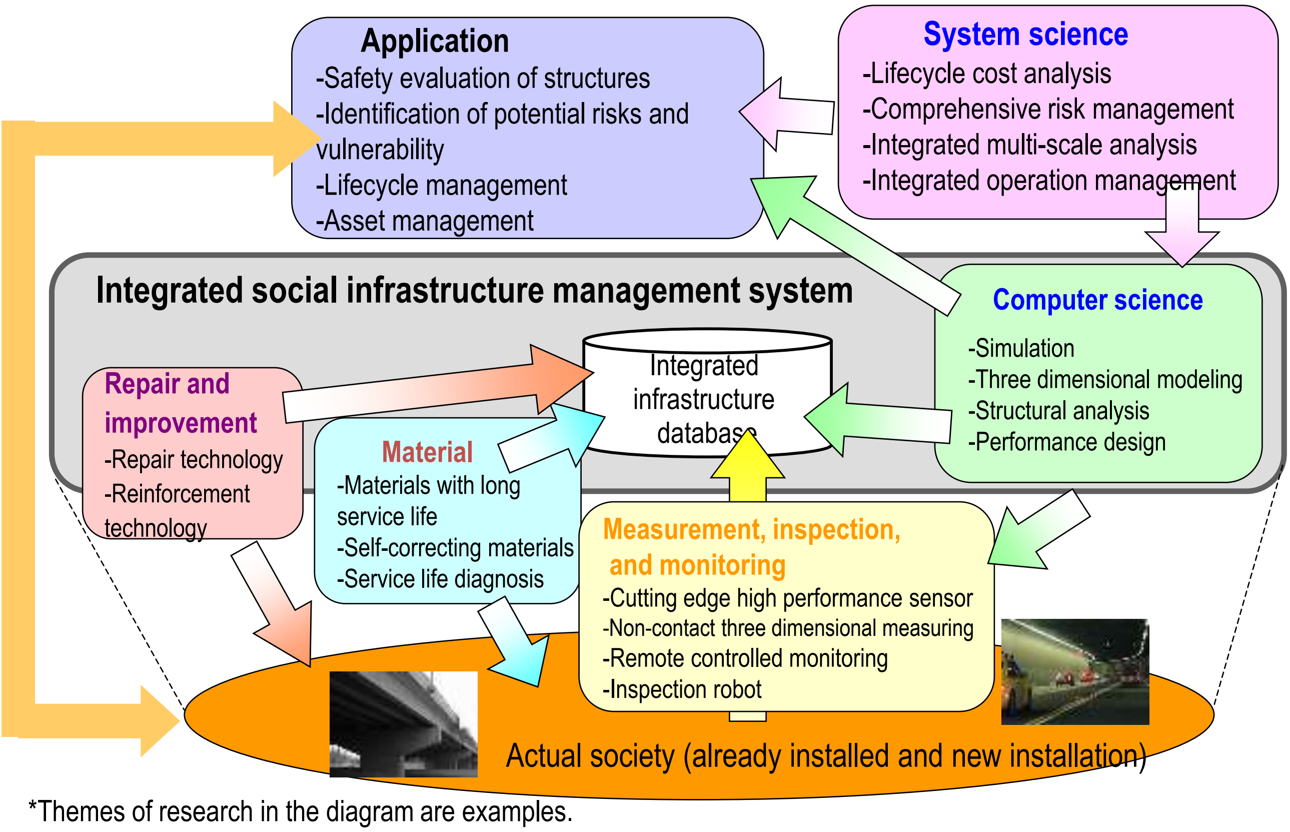
This strategic proposal suggests design, examination, and research and development in the following three categories for realizing a robust and sustainable society. This proposal especially suggests the fundamental research on integrated social infrastructure management system as the first step which becomes the common base of various research and development and effective management of the lifecycle of social infrastructures.

(1) Description of the vision of a robust and sustainable society to achieve

(2) Design of the lifecycle process of social infrastructures

(3) Design of integrated management system that assists the lifecycle management of social infrastructures

- Design of infrastructure database focusing on the information of construction, maintenance, and management of infrastructures
- Construction and operation of integrated lifecycle management system as a test
- Implementation of researches on fundamental technologies using the integrated management system (Example: Identification of the conditions of infrastructures and forecasting of remaining service life, research and development of effective and efficient methods for maintenance, management, and renewal of infrastructures, and installation of systems that can be used for repairs and recovery in case of a disaster)



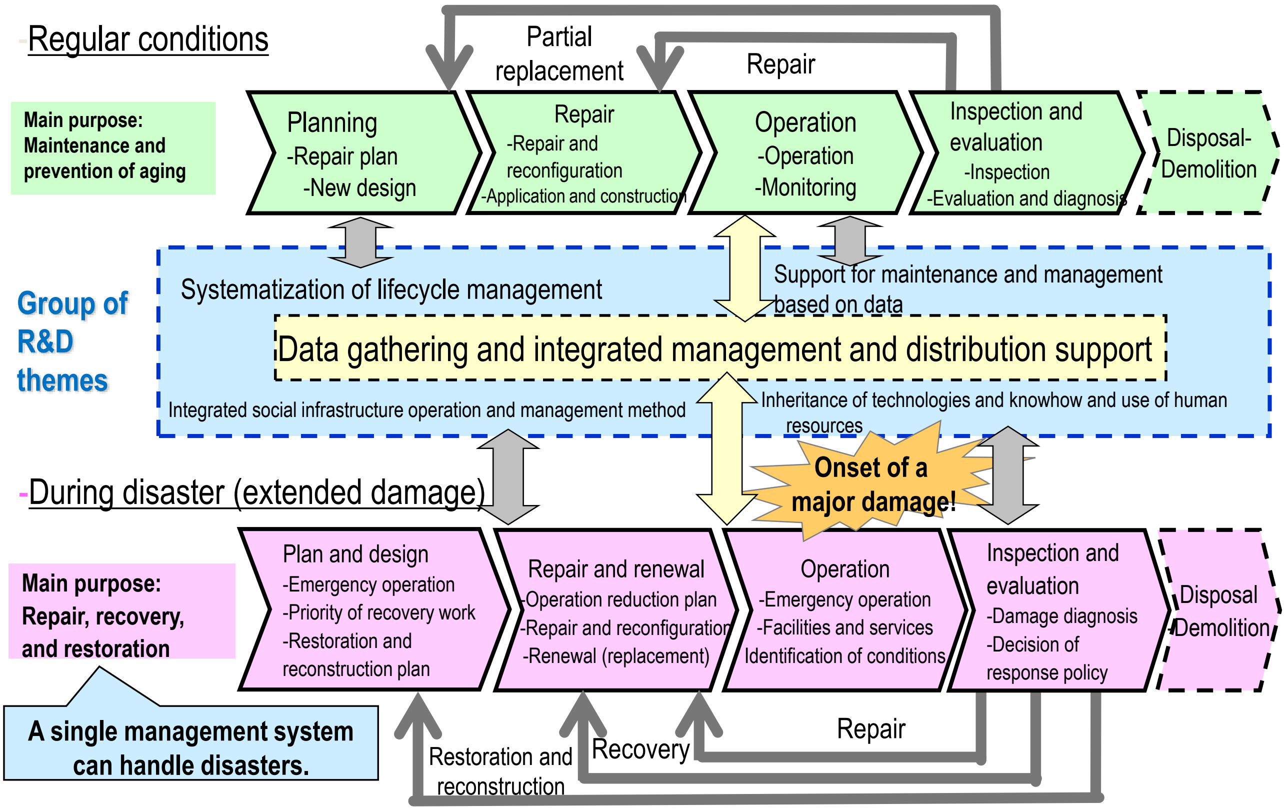

ES-Fig.1 Research and development of elemental technologies centering on integrated social infrastructure management system

Along with research and development, this proposal aims to establish maintenance engineering as common technologies and the science of maintenance as a basic and universal discipline and to sophisticate research by shedding light on maintenance work that remains insufficiently examined (ES-Fig.1).

Also, the realization of comprehensive maintenance of infrastructure requires the establishment of methods and systems to implement social scientific approaches to overcome restrictions of laws and organizations in addition to solving scientific and technical problems. System technologies are essential for solving problems, because social infrastructures are complicated systems in which hardware, software, and social, economic, and human activities are interconnected. This means that realistic strategies and systematic approaches are necessary at a national level for gradually shifting the styles of the current society and infrastructures to the direction of realizing ideal social visions by conducting researches of mutually dependent multifaceted and multi-layered themes under proper timeframe and effectively leading them to the next process or providing feedback.

In other words, this strategic proposal is intended to suggest research and development of fundamental technologies of infrastructure management to design, maintain, and develop a society where people can securely and safely live. The technological systems and the integrated management system of the lifecycle management of social infrastructures targeted in this proposal can become Japan’s unique technology that incorporates the perspectives of people, society, and the environment. And the proposed lifecycle management method and system also aim to be used for repairs and recovery processes in a time of disaster (ES-Fig.2).

In addition, the integrated management system that will be established by applying outcomes of research and development into society and repeating operations and improvements is expected to have large influences for Japan and other countries in their implementation of international businesses in industrialized countries which have aging infrastructures along with accumulated actual data and knowhow on operation, maintenance, and inspection. Integrated management is also expected to be used as the foundation of secure and safe society that supports regions with emerging economies.




ES-Fig.2 Lifecycle management method and system that can also be used for repairs and recovery processes in a time of disaster

## 3. Proposal for Issue-driven Research and Development I Future energy demand and supply landscape envisaged through a framework of cities【Executive summary in English】

This proposal describes critical areas for research and development that were designed based on a framework of cities and which are expected to be effective at reducing energy consumption and improving the efficiency of energy use in Japan.

Japan is a resource-poor country that imports most of its energy feedstock, so its energy security is strongly affected by international political and economic trends. As a result, the outlook for energy in Japan is inherently uncertain. Additionally, since the 2011 Great East Japan Earthquake and the resulting nuclear accident at Fukushima Daiichi Nuclear Power Plant, thermal power generation has accounted for a higher proportion of primary energy supply to meet domestic energy demands. This resulted in an increase in greenhouse gas emissions in 2011 compared with that in 1990, the reference year of the Kyoto Protocol. These circumstances increase the urgency of reducing energy consumption and meeting greenhouse gas emissions targets for a sustainable society while seeking for the economic growth and social welfare simultaneously.

The Japanese government approved the Fourth Basic Energy Plan in 2014. This plan describes the broad aim of energy policy: to construct a system of multilayered, diverse, and flexible structures at national level to satisfy energy demands. Although the Plan addresses supply-side factors, such as the balance of power generation methods, it also notes the importance of the demand-side changes that are necessary to deal with social, systematic, and technical changes relevant to energy. In its discussion of demand-side issues, the plan puts a particular emphasis on the promotion of energy conservation generally and points out the need for different sectors to strengthen their specific conservation efforts for the efficient (i.e., not wasteful) use of energy resources. So far, however, most discussions on demand-side energy policies have taken a national-level perspective and more specific plans according to local characteristics have not been provided yet. To encourage more efficient energy use, it would be helpful to establish a framework for examining energy issues in detail, taking a finer-grained perspective. This would also allow bolder and more specific goals for constructing an energy system for the future.

In this context, cities can be regarded as critical targets for reducing energy consumption and improving energy efficiency. Cities, by their nature, are places where great numbers of people live and engage in economic and social activities. Collectively, this leads to energy demand being strongly concentrated within cities. This is true not only in Japan but in other countries also, including both developing and developed countries. Historically, cities developed as a structure to protect the lives of residents from external enemies and natural disasters and to provide opportunities to efficiently utilize the collective intelligence and resources of the city for various social and economic activities. Yet, to maintain and strengthen the functions of cities, their energy needs have continually increased over time. As a result, the system for meeting energy demands has become too complicated to understand in its entirety, and concerns about resource depletion and environmental impact have become more serious. There is a need to examine cities in more detail, especially in terms of energy infrastructure, and explore how science and technology can improve the energy infrastructure and functionality of cities. In other words, science, technology, and innovation policies should be promoted that aim to drastically lower energy consumption and strengthen energy conservation, while at the same time contribute to improving socio-economic activities, health, and quality of life in cities.

Japan has 111 cities with a population of more than 200,000.[1] There are around 1,700 municipalities, so although these 111 cities account for only a small proportion of municipalities, nearly half of the 128 million residents of Japan live in these cities and they consume nearly half of all the energy used in Japan[2]. A study of the energy consumption patterns and infrastructure of these cities should identify ways in which a future energy system could contribute to reducing energy consumption at national level. Therefore, in this proposal, energy problems of cities were examined with a forward-looking approach based particularly on the following three perspectives aimed at identifying and organizing future energy use in cities: the movement of population among cities, the progress of energy-related technologies and social change, and the energy consumption trends in individual cities.

The 111 cities with more than 200,000 residents can be roughly categorized by size into two types: metropolitan areas such as Tokyo, Nagoya, and Osaka, which attract migrants from surrounding areas; and mid-sized cities, where the population is expected to be either stable or slowly decreasing. In metropolitan areas, many people commute to central districts during the day, but this is not common in mid-sized cities. In mid-sized cities, households are distributed mainly in the suburbs and population distribution has been becoming sparse. These characteristics of cities are already known and are expected to persist in the future [2].

Several trends in energy-relevant technological and social changes are seen in Japanese society. As examples, renewable energy is being promoted on a large scale, smart meters and dynamic pricing systems are being investigated, and energy system reform is being discussed by the government. Any of these would bring about major changes to the energy system of future cities. However, effecting such changes would be difficult because establishing a more sophisticated and highly controlled energy system requires simultaneous scale up of the energy system from local scale and integration of various technologies. Demonstration experiments of an energy management system (EMS) conducted at several sites in Japan have been mostly done at local level, and scaling up experiments have not been conducted yet. Moreover, the viability of proposed technological solutions and systems to utilize the massive amounts of energy-related information provided by the EMS and its network, which covers large areas in cities, is not yet clear.

1 Here, the 23 wards of Tokyo are collectively regarded as one city. A list of the 111 cities is provided after the references. [1]

2 The total annual consumption is estimated at $14.97 \times 10^{18}$ J.

Problems specific to different cities have also become apparent by examining trends in the energy consumption patterns of the abovementioned 111 cities. Energy consumption per capita in the household sector tended to vary in cities with a relatively lower population density. This indicates that different cities have different possibilities for reducing energy consumption although other aspects including social, economic, geographic, and climate-related conditions would have a role in household energy use as well. Differences among cities were seen in the commercial sector across all population densities, indicating that the commercial sector, too, has different possibilities for reducing energy consumption. In the transportation sector, the energy consumption per capita was negatively correlated with population density, and few differences were seen among cities of similar size.

These findings and perspectives on energy-related issues for cities lead us to recommend basic policies for energy in cities that focus on *improvement in efficiency*, *reduction of* $CO_2$ *emissions*, and *load leveling*. Here the first area, improvement in efficiency, includes comprehensive improvement in efficiency, by connecting improvements in various city functions and convenience with improvements in energy efficiency. To achieve this, it is necessary to manage the energy system at city level by designing cities around more efficient energy uses. For metropolitan areas, distributing the energy demand more evenly will be essential for making the energy infrastructure more stable and reliable, because energy demand in such areas tends to be excessively concentrated in central districts during the day. For mid-sized cities, on the other hand, concentrating and making compact scattered energy demands within a city and raising efficiency will be essential for improving the energy supply system.

Different cities may well adopt different policies in the future to realize their individual vision. Yet, in terms of energy-related technological aspects, there are several measures that should be widely adopted by cities and can be expected to improve energy systems. The following is a list of the technological measures identified. These were explored with a view to reducing energy losses, expanding the use of renewable and unexploited energy sources, and smoothing out energy balance within cities. The nine identified measures are as follows.

1. Regulation of the demand and supply system in an energy network
2. Promotion of energy conservation and the use of renewable energy in homes
3. Promotion of energy conservation and the use of renewable energy in other buildings
4. Promotion of the use of unexploited energy sources in a district
5. Spatial planning and management of land use and city buildings
6. Improvement of the energy efficiency of internal combustion engines and promotion of next-generation vehicles
7. Improvement of traffic flows in cities
8. Appropriate use of various means of transportation
9. Reduction of power losses during distribution and transformation

To put these nine measures into practice in a city and significantly improve its energy system, innovative materials, technologies, systems, and implementation methods will be most effective, although conventional technologies, systems, and methods will also be helpful. Consequently, research and development is needed to foster various ideas and possibilities. For the mid- to longer term looking toward 2030, the following five areas of research and development were identified. Progress in these areas will have broad impacts, both quantitatively and qualitatively, on cities.

- A Development of an advanced and multi-layered energy management system
- B Improvement of the energy-related efficiency of automobile traffic in cities
- C Promotion of the use of renewable and unexploited energy sources and of energy conservation in cities
- D Urban planning that incorporates the perspectives of efficient energy use and its attendant benefits
- E Use of big data to address the problem of energy consumption in cities

The potential reduction in energy consumption was estimated assuming that, by 2030, these nine measures would be implemented in all 111 cities of Japan: in comparison with the energy consumption of these 111 cities in 2010, a reduction of 36% could be achieved for the household, commercial, and transportation sectors, which would result in a reduction of 21% in the total amount of final energy consumption. This reduction is equivalent to 10% of the final energy consumption of all of Japan in 2010. However, these estimates are based on a rough hypothesis and a simplified model of calculation that uses the limited amount of available data and resources, as shown in the attachments. More detailed examinations are needed.

The aim of this proposal is to encourage action on social issues by various entities, including the government, by approaching problems through the framework of cities—where the most population lives—and by presenting visions and goals that are specific and challenging. The national government and local governments need to take the initiative in this and support the organization of systems for cooperation among universities, research institutions, and the private sector.

In a research and development program, establishing a collaboration platform is critical for enabling participants to share their individual vision, maintain motivation, and cooperate with those from different academic fields and at different research and development phases. A site for testing scientific theories and prototype models should also be considered before starting a program. Simulations of an energy system that may be applied to a city can be carried out at the site dedicated to this research purpose, and the effectiveness of proposed systems can be evaluated there. Alternatively, prototype models and methods may be implemented in actual regions within cities. It might also be practical to use already available systems for research and development and policy frameworks (e.g., specialized wards) in this program.

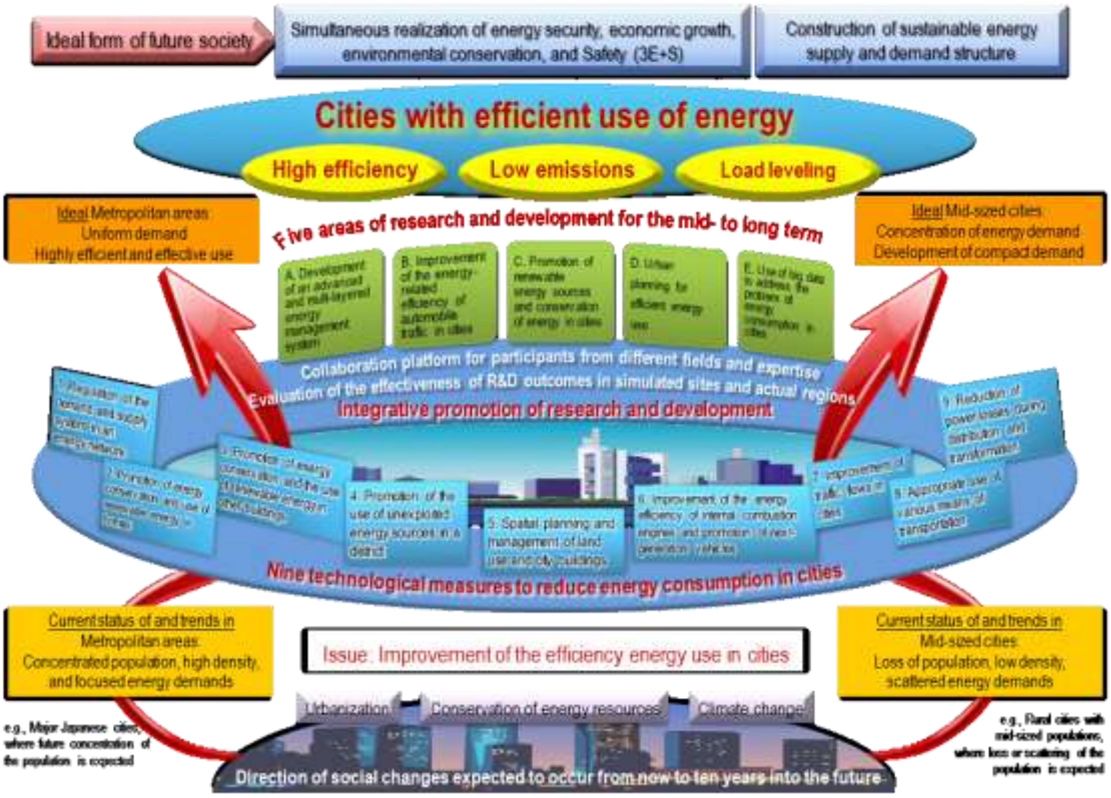



Fig. Overview of the issue-driven research and development strategy for improving the efficiency of energy use in cities.

## 4. Innovation of Reaction Process - Innovative chemical reaction in a low to intermediate temperature range through ionic and electronic control -【Executive summary in English】

This report is a strategic proposal related to the research and development (R&D) involved in innovation of reaction processes that form the bases of processes such as energy conversion, chemicals synthesis, etc. Specifically, it focuses on a technology that enables independent control of ions and electrons in a chemical reaction by a combination of catalysis, electrochemistry, and solid-state ionics. This technology can improve both reaction rate and selectivity in a low to intermediate temperature range, namely 150 to 600℃ to realize an innovative chemical reaction through the combined use of heat and electricity. Utilization of these technologies to industrial processes is expected to simplify the process, to reduce production cost and to improve energy efficiency. This research topic has now entered into a stage of active R&D thanks to novel solid-state ionics materials working in a low to intermediate temperature range. These R&Ds can contribute to the reinforcement of industrial competitiveness and the realization of a low-carbon society.

Fuel cells are a good example of energy conversion technologies, in which chemical energy from the fuel is directly converted to electricity by electrochemical reactions using solid-state ionics materials. Application of solid-state ionics materials to chemical production have just started. Chemical synthesis requires not only high reaction rate, but also high selectivity for a targeted product. The innovative chemical reaction proposed in the report aims at simultaneous improvement of both reaction rate and selectivity by enhancing reaction control through thermal and electric potential using solid state ionics materials. The new procedures will enhance catalytic activities in a low to intermediate temperature range for selective chemical reaction. In addition, the use of thermal energy can reduce the use of costly electricity as low as possible. Moreover, the combined use of heat and electricity in industrial sectors enables simplification of large-scale facilities and cost reduction. This can enhance competitiveness in various industries including the chemical industry. Furthermore, the widespread use of such technology in energy utilization and conversion may be expected to recover waste heat and to achieve higher efficiency, leading to accelerated realization of a low-carbon society.

For facilitating the R&D of innovative chemical reactions, it is necessary to employ materials that function in a low to intermediate temperature range. Recently, candidates such as sodium titanate oxide have been proposed. Also, lattice-strain effects are known to enhance ionic conductivity.

Collaborative research on this technology is very important involving not only catalyst chemistry, electrochemistry, and solid-state ionics, but also mechanical engineering, chemical engineering, process engineering, analytical science, and computational science. Implementation of the present proposal will expand these areas by merging various interdisciplinary research areas.

The R&Ds in the present strategic proposal are summarized as follows:

- R&D focused on constructing/designing reactors for novel chemical reactions
  - ➢Search of optimal electrode catalysts in electrochemical reactions
  - ➢R&D of solid-state ionics materials working in a low to intermediate temperature range.
  - ➢R&D of optimal control on catalysis functions in chemical reactions including electric potential control.
  - ➢R&D for material search/development and method of chemical reactions through feedback from the basic research.
- Theoretical and experimental investigations on ion and electron transfer phenomena on surfaces and interfaces
- R&D toward the application for reaction processes
  - ➢Study on the evaluation of energy efficiency, etc., based on Life Cycle Assessment (LCA) in reaction processes as well, and selection of chemical reactions/processes based on the results of such evaluation
  - ➢Applied research of the designing of reactors toward process designing

## 5. Fundamental Technology of Energy Carriers for Transportation, Storage and Utilization of Renewable Energy【Executive summary in English】

This strategic proposal recommends that the government should strategically promote the research and development of fundamental technology of energy carriers, i.e., energetic chemicals, for massive introduction of renewable energy.

Implementation of renewable energy is required to resolve the problems of fossil fuel depletion and climate change. On the earth, there are considerable amounts of available renewable energies such as wind power, solar irradiation and hydraulic power, and they are expected to serve as primary energy feedstock for future human society. However, Japan does not have a large land area, so the available amount of solar and wind power is smaller compared to other regions. If we want to introduce a large quantity of renewable energy, we should import such resources from countries having abundant renewable energy. The renewable energy has two inherent problems as follows.

1) The renewable energy resources are unevenly distributed globally and locally. A huge amount of solar irradiation is available in the desert areas close to the terrestrial equator, while wind power is often abundant at the high latitudes such as Hokkaido and Tohoku areas in Japan. On the other hand, they are not abundant in energy-consuming cities.
2) Most of the renewable energy is associated with large daily and seasonal fluctuations, so they should be leveled off as base energy supplies. Solar and wind power are affected by weather and fluctuates over a period of several days or weeks, which is much longer than the day and night leveling off of electricity.

To materialize a society utilizing massive renewable energy, these problems on transportation and storage of energy should be resolved. Renewable energy has already been widely used as an electric power supply, although electricity is not suitable for long-distance transportation and large-scale storage. Hence, it is most appropriate to produce energy carriers such as hydrogen, ammonia, organic hydrides and metals/metal oxides from renewable electricity or directly from renewable energy, and to transport and storage them before finally supplying them as electricity, mechanical power and/or heat.

There are only a limited number of known technologies for producing energy carriers from renewable energy, and, in particular, direct conversion of renewable energy to energy carriers is extremely difficult. Moreover, there are only a few technologies to obtain electricity, mechanical power and heat from such energy carriers. For instance, hydrogen can easily be produced by water electrolysis and used for producing secondary carriers; it is being used for commercially available fuel cells. However, we have only primitive technologies for synthesizing ammonia and organic hydrides from water with nitrogen or hydride-precursors. The direct-carrier fuel cells and direct-carrier engines also require fundamental research and development. Since our country has set forth a goal of stable utilization of renewable energy, we should strategically promote basic and applied research in order to lead the world by developing these technologies.

The energy carriers mentioned above have individual characteristics in their energy density, utilization method, safety, stability, cost and so forth, so they should be selected and used depending upon the purpose. At present, there is no single carrier that is generally most promising. For example, it is assumed that gaseous hydrogen will be used for fuel cell vehicles, but hydrogen cannot be stored in large scale and for long periods of time. For such storage, liquids and liquefied gases such as organic hydrides and ammonia are clearly preferable. Hydrogen and ammonia can also be directly supplied as fuels into internal combustion engines, but organic hydrides should not be burned because of their recycling as precursors. Therefore, extensive research work on various conversions of carriers for production and utilization is mandatory, and it is most important to obtain sufficient scientific knowledge to judge which carriers would support future energy systems based on renewable energy.

So far in our energy technology development, electricity has been identified as the most useful final energy source, so that the production of energy carriers from electricity have not attracted much attention resulting in that the related technologies are left primitive. In a future society based on renewable energy, however, electricity will be a source of energy, and the production of carriers from electricity will play an important role in the utilization of renewable energy. Moreover, direct production of carriers from renewable energy such as solar irradiation will be the ultimate technology. Our country has much advanced technologies in electrochemistry, catalysis and IC engines, so we should prepare for large-scale dissemination of renewable energy by exploiting these advantage technologies for the development of carrier technologies.

The energy industry is the basis of the national economy. It is presently supported by petroleum and natural-gas plants and should be replaced by the renewable energy carrier and/or derived electricity plants in the future. The social receptivity, compatibility to present infrastructures, environmental friendliness, and margin of safety should be investigated from a wider perspective, as well as the research and development of elemental technologies. Our country should develop technology in renewable energy carriers ahead of other countries and supply them to the world for the promotion of renewable energy as a world leader in science and technology.

A variety of disciplines such as chemistry and chemical, mechanical and systems engineering should be integrated to address the science and technology for energy carriers. Furthermore, a wide range of cooperation and collaboration is necessary from atomic-scale reaction mechanisms in electrochemistry and catalysis to real-scale reactors design, system structuring and environmental impact assessment. This synergistic attempt with a common view of energy conversion should certainly cultivate human resources of chemistry and chemical, mechanical and systems engineering, which can put R&D themes on energy in perspective.

## 6. Consolidated Research Initiative for Sustainable Nitrogen Cycle 【Executive summary in English】

Nitrogen cycle is essential for the sustainability of the human society. We should promote a consolidated research and development（R&D）initiative which aims at understanding its status and its mechanism as well as at establishing technological capability to make it sustainable.

Modification of the environment due to human activities is a serious issue that threatens sustainability of the human society. Modification of the global biogeochemical cycle is one of its most important aspects, along with climate change and biodiversity loss which have already been recognized as major issues internationally. In particular, modification of the nitrogen cycle by synthesis of chemical fertilizers as well as by air pollution has already reached a magnitude comparable to that of the natural biogeochemical cycle. Water pollution due to nitrates and ecological impacts of acidification and eutrophication of water bodies have occurred in various places. Also, movements of matter beyond national boundaries have been discerned. The modification of nitrogen cycle is deemed to have exceeded the limit of sustainability.

Nitrogen fertilizer is indispensable for food production. We should develop and disseminate such technologies that fulfill the needs for food production as well as those for reduction of environmental burden due to nitrogen together, including those in agriculture and livestock business, in treatment of waste water and solid waste, and in monitoring and control of the nitrogen cycle in various scales.

East Asia, which includes Japan as well, has a large population, and accordingly its environmental burden of nitrogen is large. It is ever more increasing particularly in such emerging economies as China and Southeast Asia, because of their rapid industrial development and changes in food choices, although environmental regulation is also being strengthened. It is crucial to act proactively to reduce environmental burden before any large-scale damage appears evident.

To do this, both national and international policy measures are needed. In order to provide scientific knowledge to them, we need to develop capability to simulate the nitrogen cycle over the East Asia as well as the effects of technological options on it.

cost-effective monitoring and abatement technologies.

International scientific programs that deal with global environmental issues under the auspices of the International Council of Science（ICSU）are being reorganized as "Future Earth". International funding schemes of R&D are also being developed. Thus, the time has come to work on solving the problem of the nitrogen cycle in the East Asia by taking advantage of the above-mentioned frameworks.

In this context, Japan, as suggested by the follow-up of the Third Basic Plan of Science and Technology, should promote R&D aiming at sustainable nitrogen cycle by overcoming administrative boundaries. We call it "Research Initiative for Sustainable Nitrogen Cycle". It principally consists of R&D projects that focus on three spatial scales: East Asia, watershed, and farm. Each of them should include a common scientific basis and a scheme for integration of entire research outcomes.

（1）**East Asia**. Integrated process-based models of the nitrogen cycle applicable to East Asia are to be developed. Making use of them, the complete nitrogen balance is evaluated. Spatio-temporal data of the nitrogen cycle as well as of the natural and social factors causing possible changes to it, both at present and in the past, will be collected and organized. Model experiments to represent the actual states will be carried out. Also, sensitivity studies will be done in order to clarify effects of technologies and policies. The models are also applied to multiple future scenarios in order to evaluate technological options.

（2）**Watershed.** A river catchment, which has a length scale of tens of kilometers, and which is heavily affected by human activities, is to be studied as a system of biogeochemical cycle. Focusing on the nitrogen cycle as well as the factors that can change them, enhanced observations and surveys will be made, and a consistent data set of the nitrogen balance would be available. Also, field experiments should be made in the watershed with implementation of enhanced measurements, in order to evaluate impacts of technological options.

（3）**Farm**. Intensive studies will be made in an experimental farm of a length scale of hundreds of meters, which is precisely maintained and measured. Detailed observations and modeling of basic processes of the nitrogen cycle in the soil-plant complex in the cropland will be made. Abatement technologies in agriculture will be developed and tested in experiments with detailed observations, and their intended and unintended effects will be evaluated. Also, appraisal of measurement technologies should be made in the field.

（4）**Basic R&D**. R&D projects that contribute to（1),（2）and（3), including those to fully understand mechanisms of nitrogen cycle and those to develop technological options, will be planned in a collaborative way.

The R&D initiative should include the following subjects and need inter-disciplinary collaboration.

- Observational and experimental studies to understand processes and mechanisms of nitrogen cycle.
  - Understanding of processes（biological, soil, hydrological, geochemical etc.）that comprise the nitrogen cycle.
  - Understanding of the overall nitrogen cycle and its degree of modification.
- Development of measurement technologies. They will facilitate observational studies and will also be incorporated in the abatement technologies.
- Development of simulation technologies.
  - Model development, calibration and validation based on the data of nitrogen cycle in the past.
  - Evaluation of intended and unintended effects of abatement technologies by prognostic experiments with scenarios of technological options.
- Development of abatement technologies, and experiments to assess them. These experiments involve comprehensive observations, which will comprise feedbacks to improvements of the technologies.
  - Agricultural technologies: breeding of such crop varieties that can utilize nitrogen fertilizer effectively; development of fertilizer products; techniques of applying fertilizer, controlling water, and tillage.
  - Technologies to recycle（as fertilizer）or treat（denitrify）animal manures and human wastes.
  - Social technologies to make incentives for reduction of nitrogen burden, such as tax reforms.

Implementation of this R&D initiative needs collaboration cutting across administrative boundaries. Also, for its success, it is mandatory to cultivate a research community, which shares the recognition of the existing issue of sustainable nitrogen cycle and moves forward beyond disciplinary boundaries. The community should include, besides researchers in the conventional sense, those who are willing to participate in demonstration experiments both in Japan and in foreign countries.
With this R&D initiative promoted, it will be possible to comprehend nitrogen cycle and also to plan and to implement policy/technology measures to reduce its environmental burden, at such multiple scales as farms, watersheds, and East Asia. Also, from the viewpoint of science-technology diplomacy, it is necessary to work ceaselessly to form science-based advice to international policy-making, partly by way of

international assessments on nitrogen cycle. The knowledge gained in this R&D initiative, particularly, observational data, standard models, results of simulations, indices for evaluation, should be publicized, shared internationally, and be maintained for the years ahead. That can be Japan's leading international contribution.

## 7. Science for Energy Policy: R&D on Engineering-Economy Models 【Executive summary in English】

Engineering‒economy model for energy policy is a methodology for quantifying the interaction between energy technologies and economic activities. The final aims of this model are to provide evidences based on science for energy policy and to give energy management strategies in industries. On the other hand, this report focuses on the importance of governmental support for the R&D on engineering‒economy model as a basic research. Two major approaches exist for energy modeling, i.e. deductive bottom up approach and inductive top down approach. Integration of these two approaches will be the essential research target of this program. In addition, further supports for this scientific community are required.

In order to overcome global issues, e.g. resource exhaustion and global warming, and to achieve sustainable society, it is indispensable to possess a firm energy policy. In addition, research and development of energy technologies should be in accordance with this strategy. Contribution to the total energy issues must be quantitatively evaluated, and technology roadmap based on scientific evidence must be developed. Engineering‒economy model must be developed and improved to provide quantitative evidences for those discussions in an autonomous community.

The issues mentioned above lie at the boundary between engineering and economy, and the present engineering‒economy model remains at an immature stage as an academic field because of a lack of interactions between the two disciplines. Thus, it would be difficult to promote it by competitive funding schemes. A neutral multidisciplinary and open research environment to conduct related basic research must be established. A possible pathway would be to fund and support continuously interdisciplinary research activity developed at a research base or an academic society. To do this, it is mandatory that both policy makers and scientists should respect their roles each other and define their codes of conduct in order to establish a healthy relationship. Only with these, it can be expected that a new multi‒disciplinary academic field will be established and energy policy making can be justified.

It is essential to cultivate young scientists in this society. Thus, active support for human resources development is also a critical issue. In addition, more efforts to develop career passes for young scientists are also required. Not only academic posts, but employments in local governments and industries should be considered as new possibilities.

Research for engineering–economy modeling is an activity for quantifying the interactions between technologies and economic activities, and is related to all social activities. Thus, the achievements of the present strategic program can be applied not only to energy policies but also to very wide fields. Its impacts on the industry and the society will be enormous.

## 8. Enhancement of National Strategy for Energy Research and Development【Executive summary in English】

This proposal summarizes the measures to enhance national strategy for energy research and development. The challenges requiring earnest attention in the areas of Japan's energy research and development, and measures for promoting such R&D, are summarized in various national plans that have been put forward by the government, such as the "Basic Energy Plan", its second revised edition, published in June 2010, the "Innovation Plan for Environmental Energy Technology" that was announced in May 2008 by Council for Science and Technology Policy, and the "Basic Policy on Science and Technology" that was reported by the Council in December 2010. It has been pointed out that it is also necessary to enhance the functions for planning and promoting comprehensive energy plans across all offices and ministries, as well as the functions related to basic, fundamental research, as covered by this proposal, but the planning and the execution of concrete measures have yet to be done.

An energy plan is a national program that is developed based on the collected goals and expectations of every social activity and individual life. On the other hand, the plan is an extremely complicated comprehensive policy that is affected by uncertain elements such as demographic dynamics, the structure of industry, and the international resources market. Our country has promoted the development of new technologies for energy utilization to make international contributions to the stable supply of energy as well as the prevention of global climate change. However, a master plan for energy that is agreed to and shared by all levels of people in Japan, and a consolidated plan for energy research and development that is part of that master plan, have yet to be realized. The US created a department to be responsible for energy in the 1970s and established a system for comprehensively discussing all energy issues on an equal footing and developing energy plans. The UK followed three years ago. We face a pressing need to construct an energy master plan that is tailored to the needs of our country.

Against this background, the Great East Japan Earthquake and the Fukushima Nuclear Power Plant Accident in March 2011 led to an unprecedented wide-ranging disaster and forced Japan to reconstruct its national social, economic and administrative systems. Central to the challenge is ensuring a supply of energy so as to support all the activities of our country. Consequently, the people of Japan are looking to the government to draw up a comprehensive mid- and long-term design for safely and stably providing energy in response to demand in Japan.

From these viewpoints, we propose the following points.

[Proposal] The nation should enhance the functions needed to plan and promote both a national master plan for energy and a consolidated plan for energy research and development.

(1) To effectively promote research and development in energy-related fields, create a national mid- and long-term master plan for energy, and a consolidated plan for energy research and development that is driven by issue search (research into and discovery of social wishes), across offices and ministries, and enhance the system for, and function of, promoting the plans with the collaboration of industry, academia and government.

(2) Make the process of plan development transparent to the public, to utilize the knowledge and experience of researchers, engineers and administrative officials that are involved in energy research, development and commercialization, while sharing a consolidated plan for research and development.

(3) To promote the long-term challenge for R&D, given the high degree of difficulty presented by energy-related fields, set and adhere to basic policies for plans concerning basic and fundamental research. Furthermore, establish a basic research center for setting policy goals in the energy-related fields and promoting problem-solving collaboration among researchers in different fields and cooperation between basic research and application research and development, under the guidance of the center.

For a "consolidated plan for energy research and development," it is necessary to scientifically examine the overall demand for and supply of fossil resources, nuclear power, and renewable energy, and to indicate the priority of focused measures, the scale of the budget to be allocated to some project and the reasons for setting such a priority and budget, so as to ultimately realize the national goals affecting people's lives from a mid- and long-term standpoint. This release is absolutely essential to gaining a common understanding from all the researchers and project managers as well as the populace in the role of energy users. The related offices and ministries have already made some efforts to develop and promote energy policies under the initiative of Council for Science and Technology Policy, but these efforts have not been satisfactory from the above standpoint.

Since energy is positioned as a prerequisite for all social activities, it is more important for scientists and engineers to maintain more interaction with society and positively participate in national planning in a neutral position. Consequently, it is necessary for scientists (including not only natural scientists but also social and humanities scientists) to take the initiative in promoting issue search (research into and discovery of social wishes), so as to recognize potential future social needs in advance and to link these needs to the development of science and technology while proposing R&D challenges to society.

Furthermore, in order to collect opinions from all levels of the populace, for instance, we should assume the use of a forum such as an "innovation council" which is being considered by the government. In such a forum, it is important to guarantee the transparency of discussions in open environments. Hence, we propose that a secretariat of the council should employ experts in science and technology for a given period to actively receive and scientifically understand proposals and views from academia and industry. In addition, to proceed with policy planning in a scientific manner across all offices and ministries while collecting various opinions, we propose that experts with cross-cutting perspectives should be recruited to decision-making positions in an administrative organization and measures for the development of such human resources be defined.

Basic and fundamental research related to energy is mainly left up to independent researchers working in universities and institutions. We have often heard the opinion, however, that it is very difficult for young researchers to become involved in basic research requiring large amounts of time because the research presents a high risk to the researchers and research results are nowadays expected in the short term. In addition to the above research into and discovery of social wishes, the basic research center should continuously promote basic research into innovative challenges and leading-edge fundamental research such as measurement, analysis, and simulation that supports application research and development and commercialization in line with basic research. A detailed picture should be drawn of the basic policies that must be observed by the country, through industry-government-academia discussions in the above innovation council and other forums.

We have proposed that the basic research center in the energy-related fields should be established in the Tohoku region as one of reconstruction measures in the wake of the Great East Japan Earthquake and the Fukushima Nuclear Power Plant Accident. The promotion of the basic research center and network-type R&D driven by the center can make an important contribution to the reconstruction and also Japan's science and technology innovation.

## 9. Phase Interface Science for Energy Efficient Society【Executive summary in English】

This report proposes that the government should strategically promote the basic research on "Phase Interface Science for Energy Efficient Society," which must be a key for highly efficient energy utilization.

In order to overcome global issues such as global warming and resource exhaustion and establish a sustainable well-being society, it is indispensable to attain ultimate energy efficiency as well as to develop novel energy technologies by keeping a wide range of perspective from the supply side to the demand side. Unfortunately, there is no confirmed single energy resource that can substitute enormous fossil energy consumption economically and quantitatively, even if we envision the year of 2030. Therefore, it is mandatory to satisfy the following two requirements for energy technologies to be developed regardless of renewables or non-renewables, *i.e*., a substantial volume which meets huge global energy consumption, and a sufficiently low cost to be competitive against conventional energy supplies. Considering the energy issues broadly from viewpoints of revolutionary and quantitative contributions, it becomes clear that we should promote research for basic science, design, manufacturing and control technologies for phase interface phenomena.

In any energy device or system, interfaces or boundaries exist between different materials and different phases such as solid, liquid and gas, where mechanical, chemical and/or electromagnetic phenomena take place. All losses, which hider the achievement of theoretically best possible performance of energy technologies, originate from irreversibility in the energy conversion, transport and storage processes, and they take place mostly at phase interfaces. It is thus crucial to drastically reduce these losses for much better energy saving and energy efficiency and for new energy introduction. In other words, the performances and efficiencies of real energy systems can be pushed toward the best limiting values by exploring the entire fundamental processes of energy transport and conversion and also by enabling designs that minimize the irreversible losses. For example, Fig. 1 shows phase interface phenomena found in an integrated gasification fuel cell system (IGFC), which is considered as an ultimate power generation system in the future. Analyses and advanced design methodologies of various phase interfaces, *e.g*., fuel cell electrodes, gas turbine blades, gasification and exhaust gas catalysis surfaces, lean burn combustion flame interfaces, gas separation membranes, will as a whole lead to ever more efficient energy utilization and global warming prevention. As in this example, deepening the basic phase interface science and developing control/ optimization technologies will enable drastic reduction of energy losses and creation of unprecedented functional processes. This will eventually strengthen the nation's lasting competitiveness in the energy related technologies through drastic improvement in the efficiencies and costs of conventional as well as new technologies.

In order to achieve these goals, analyses for understanding phase interface processes and elementary steps as well as design sciences for optimizing and controlling the phase interfaces are required. Phase interface phenomena take place at multiple levels from nano, meso to macroscopic scales. In order to exploit breakthroughs in nano scale material research for designing macroscopic scale systems, it is required to handle comprehensively the phenomena of diverse scale ranges across tera orders. Development of measurement techniques and modeling and simulation tools, which can holistically analyze and design multi-scale systems, will make it possible to reflect fruitages from advanced basic research in real applications. In addition, collaboration and amalgamation of analytical and synthetical researchers is indispensable. A breakthrough can be achieved only when multidisciplinary scientists and researchers, *e.g.*, material, chemical, mechanical, electrical, physical and mathematical researchers, are invited to gather together and collaborate under the shared mission objective for energy. In addition, it is very important that the basic research outcomes should eventually be integrated into mass production processes. In order to facilitate this knowledge transfer, it is recommended to feedback required functions and also environmental constraints to early stages of basic research. It would help if institutional measures are taken to form researchers' networks between academia and industry, and social and economical needs are taken into account when thematic prioritization is made in the basic research.

Phase interface phenomena are the processes that energy carriers are transferred and converted between different materials and phases, and in fact they are found in every human activity. Thus, the outcomes of phase interface science research will produce extensive spill-over effects being applied not only to energy related technologies but also to a much wider range of applications, so their impacts on the industry and the society will be enormous.

## 10. Synthetic Study on Forecast Models of Regional Environment and Ecosystems –Towards the planning of adaptation measures for climate change-【Executive summary in English】

Effects of global climate change on regional ecosystems should be forecasted by observation and modeling. Such study is necessary to accelerate revitalization and preservation of ecosystems and to contribute for regional sustainability. In order to facilitate it, the promotion of the synthetic study is proposed, synthesizing following two issues. At first, creation of knowledge & technology and support for problem solving will be synthesized. Furthermore, each ecosystem model will be synthesized into a basin area model.

It is the social expectation that environmental problems, which may effect on the human activities and to threaten the survival, are resolved, and science and technology are expected to contribute to resolving them. The research field for the resolution is environmental sciences. Even though problems are on the regional level or on the global level, it can be said that environmental sciences have no reason of their existence unless they aim at problem solving.

Climate change is the most problem among the environmental problems facing humanity at the present time. How an ecosystem, the base of life in the regional society, shifts by climate change? Which of adaptation measures for preventing these shifts should be chosen? For these serious questions, science and technology must provide an answer.

In light of the above, the synthetic study should be promoted on development of models for estimating effects of climate change on a region and to plan the adaptation measures. Details of the study are as follows:

First, focused on a basin area which is for water and material circulations, human life and economic activities, some land, freshwater , and ocean ecosystems are selected which have a close relation to social activities such as primary industries and human living. Then, trends in climate change and the distribution of biological species is observed, as well as a model representing the response process of biological species against the multiple stresses is built up, and trends in change of biological diversity and ecosystem services are simulated. Based on these results, some measures to protect and control the ecosystem are planned, and some concrete actions to revitalize and conserve the ecosystem are promoted. And finally, combining each ecosystem model, the total system of a basin area will be confirmed.

In order to promote the study, participation of various stakeholders is necessary, such as ecologists, engineering scientists, engineers, local governments and residents.

Against climate change, many efforts have been accumulated until now mainly on global measures. In order to enhance actions against this issue, the efforts in each region should be strengthened. Science and technology will develop to contribute for problem solving as well as creation of knowledge through the promotion of the proposed approach focusing on region. At the same time, the approach will realize the conservation of living base and sustainability in the regional society. Moreover, it will contribute to the global sustainability by providing methods and tools developed in Japan applicable to studies in foreign countries and regions.

## 11. The Promotion of Research and Development for the Reduction of Greenhouse Gas Emissions - Realization of a Scientific and Technological Innovation by Forming a Network of Industry, Government and Academia -【Executive summary in English】

(Message from Prof. Hiroyuki Yoshikawa, the director general of CRDS)

Reducing greenhouse gas emissions is an urgent and important issue for the whole country. Especially since advanced technology is expected to play a central role, the scientific community of industry, government and academia needs to address this matter with their utmost effort.

In this strategic proposal, the future direction of the research and development for the reduction of greenhouse gas emissions such as $CO_2$ (carbon dioxide) is proposed.

The Hatoyama Cabinet declared his policy worldwide to reduce Japan's greenhouse gas emissions by 25% by 2020 compared to the 1990 level. Furthermore, Japan is to aim at reducing the level by 60 – 80% by 2050.

Considering that the only products which have industrial competitiveness in the current global market are limited to sustainable products related to renewable energy or energy conservation, estimating a low reduction rate would mean giving up on improving competitiveness. In light of this, aiming for a 25% reduction rate would be nothing less than declaring a positive intention of maintaining a high level of industrial competitiveness continuously into the future.

Therefore, a 25% reduction can only be fulfilled by enhancing the nation's strength with the efforts of the whole society including the revitalization and innovation of industries. With this aggressive goal in mind, it will require efforts in every sector of government, industry and the nation to accomplish the task. We understand that we need to make a national commitment to address this issue, while establishing a new cooperative framework which we have never experienced before. Among these, in the research and development of science and technology, we need to initiate researches urgently by making positive plans describing in detail the priority issues and implementation of the related disciplines which include a wide range of research processes such as discovery and basic research, design and engineering, product development, etc. Judging from the characteristics of scientific researches, though the goal of these plans will be set to 2020, it is only natural to expect keeping in mind the fact that these researches will deeply progress and contribute for a long time in the coming future. 2020 is closing in fast and we can only make a truly effective solution by placing it in a long-term perspective.

The reduction of greenhouse gas emissions is a new issue even in science and technology, so advanced technology plays an important role. The science community has the responsibility to expand the possibility of significantly reducing greenhouse gas emissions through basic research, while at the same time, provide the necessary science and technology to all sectors whenever requested in a timely fashion.

The necessary science and technology covers a wide range from the basic researches of nanotechnology and life sciences to system technology for commercialization or a specific product design and manufacturing technology. Therefore, Japan's science community needs to concentrate their scientific wisdom to promote R & D, and realize scientific and technological innovation under the cooperation of industry, academia and government, by overcoming not only the barrier between natural science and social science but also the barrier between basic research and applied research.

In order to meet such needs, scientists must act urgently. Deepening and accelerating researches goes without saying. They also need to start action immediately, building discussions, weaving new networks at universities, research institutes and academic meetings, in order to provide the necessary and appropriate information to society.

Needless to say, the full support of government and funding organizations will be indispensable towards the actions of the scientific communities trying hard to realize the significant reduction goal.

With this proposal we hope to stir up broad and diversified discussions and actions which will lead to the actual reduction of greenhouse gas emissions.

## 12. Proposal for Establishment of Two Strategic Organizations in order to Lead the World in Science and Technology by Technologies to limit Carbon Dioxide Emissions【Executive summary in English】

Japan is about two steps ahead of the rest of the world in terms of the dioxide emission control technology, because of concentrated efforts against the oil shocks in the 1970's, the subsequent framework for industrial promotion, and the Japanese disposition.
To keep this advantage and maintain this field as the vital base for the Japanese economy, it is necessary to always examine two elements which are now almost disregarded.

The two elements are: "Resource Limit of Environmental and Energy Technologies"; and "Strategy for Overseas Transfer of Environmental and Energy Technologies."

The global effect of environmental and energy technologies will not appear until the technologies get across not only advanced countries but also developing countries. Most environmental and energy technologies need rare-earth metals. Therefore, some technologies are not be distributed because of resource restriction. Such situations should be constantly monitored, and an institution or an organization is necessary for this purpose.

In the year 2050, Japan is predicted to occupy 1% of the world population as well as the world energy consumption. Therefore, only after transferring the Japan’s excellent dioxide emission control technology to overseas, reduction of carbon dioxide emissions will be realized globally. In addition, the emissions from Japan can be substantially regarded as zero by the international contribution through technology transfer. For that reason, it is necessary to continuously consider transferring which technology to which country at which timing, and an institution or an organization should be responsible for this.

This proposal recommends establishment of the above two organizations and briefly explains the details with some backgrounds.

## 13. Fundamental Technologies for Extended Solar Energy Utilization - Solar Cells and Solar Hydrogen Production –【Executive summary in English】

This strategic program proposes an R&D strategy for establishing a basis to extend the solar energy utilization through such technologies as the development of new materials and the utilization of photosynthesis function.

Various global problems have been emerging in the 21st century. Among others, it is an urgent and long-last important issues for us how to manage both the sufficiency of the increasing energy demand and the reduction of $CO_2$ that is the main reason for the climate change. A basic revolution scenario for energy configuration is as follows.

(1) Implementation of energy conservation
(2) Maximum utilization of renewable energy including natural energy
(3) Effective use of fossil fuel, and CO2 capture & isolation
(4) Maximum use of nuclear power

As the solar energy is mostly promising for its inexhaustible and clean feature in the natural energy (2), the energy generation technology by the conversion of the solar energy is reported in this proposal.

The practical use of the solar energy has been already advanced focusing on the silicon solar battery with the government investment for the improvement of its efficiency. However, as the cost reduction is limited, a dramatic expansion of the usage is difficult with the present technology.

On the other hand, in terms of the organic solar cell expected for significant cost reduction and the promising hydrogen generation technology using solar light, the systematic investment for basic R&D has not been made in the private sectors, leaving various R&D issues behind. Although there are technical seeds at some universities/national institutes , no full-fledged government investment has been made.

As the universities/national institutes in Japan possesses high potential in such fields as material science, chemistry, and biotechnology, the integration of those potential and the engagement in the research issues may result in satisfactory achievement with the formation of a basis to extend the solar energy utilization.

Specific R&D issues to which the government should invest to solve are shown as follows, which should be promoted in mid- and long-term basis as a technology package through integration and cooperation.

(1) Fundamental technology of solar photovoltaic generation using organic materials
(2) Fundamental technology of solar hydrogen generation
(3) Construction of design theory as energy conversion system (common issues for (1) and (2) )

It is extremely important to solve these issues by applying cutting-edge technology of material science and biotechnology and through the fusion of research in physics, electronic engineering, chemistry and biology. An R&D system to promote the fusion and cooperation must be arranged to execute this R&D project. It is also necessary for success to establish the cooperation system among different ministries that would be supplemented with related and simultaneously executed projects such as those of NEDO etc.

This proposal is an investment strategy for the basic research issues for highly innovative influence utilizing the strong points of Japan. After the establishment of the technological basis and diffusion of practical use, the returns to be gained in future are as follows:

(1) Contribution to the maintenance of global environment
(2) Direct contribution to the improvement of energy self-sufficiency rate of Japan
(3) Creation of new energy industry with high competitiveness.

This strategic program should be started urgently and carried out in the mid- and long-term scope.

## 14. Energy Harvesting Technologies【Executive summary in English】

The "Energy Harvesting Technologies" is a technology for utilizing the energy widely sipersed but not used now, such as electromagnetic wave, indoor artificial light, body temperature, waste heat, human action, natural vibration etc..

The dispersed energy has not been paid enough attention because the energy is generally small and unstable, difficult to convert into stable electric energy, and there are no elements or devices operable with such slight electric power. However, owing to the recent development of low power consumption semiconductor devices, an element operable with slight electricity is invented, which brought in the reality of dilution dispersion energy utilization.

Dilute dispersion energy utilization technology is composed of following technologies: energy conversion; energy conversion material; energy storage; energy transfer; system control; low power circuit; packaging; and other technologies. These technologies currently cannot support the slightness and unstable features of the dilution dispersion energy sufficiently, especially, the energy conversion technology including the energy conversion material technology is remained unestablished. As a result, there remain numerous basic technological problems to be solved.
At present, due to the research work mainly at universities, the technological level of Japan is high compared with other countries, however, in order to establish basic technology for the dilution dispersion energy utilization technology, more intensive R&D effort is required.

The R&D themes can be broadly divided into two as follows:

- The basic research on elemental technologies composing the dilute dispersion energy utilization technology including: energy conversion; energy conversion material; energy storage; energy transfer; system control; low power circuit; packaging; and other technologies.

- Development of specific application method of the dilute dispersion energy conversion technology and the application system

For carrying out the R&D project, a proposed formation is as follows:

Sub teams are formed composed mainly of the researchers of various energy conversion technology, and the common technology team is formed composed of the researchers of the common technology (energy storage, energy transfer, system control, low power consumption circuit, packaging, and other technologies) that covers all the sub teams horizontally. The sub teams and the common technology team work closely together on the basic research for specific applications.

## 15. Molecule and Ion Technology of Hydrogen Energy System【Executive summary in English】

The hydrogen energy system, possesses a potential to achieve high energy efficiency of fuel cells and other applications, and its R&D is promoted. However, the system has not had an advantage over the existing systems in total energy efficiency between primary energy collection and consumption. Moreover, the system is now facing big problems such as costs, durability, and so on.

To overcome above problems, a breakthrough that is not an extension of existing technologies is necessary, and R&D should be promoted based on fundamental physics and chemistry including clarification of reaction and deterioration mechanism of fuel cells and hydrogen occlusion material, and subsequent new material searches. Therefore, we propose the following assignments including promotion methods:

[1] Clarification of physical and chemical mechanism of fuel cell and material searches
- Clarification of movement, transportation, and reaction of hydrogen (molecules and ions), water, and catalyst elements inside of a catalyst electrode and an electrolyte film of fuel cells, and accompanying deterioration mechanisms
- Search of electrolyte films with high conductivity and high stability
- Search of materials and structures of catalyst electrode with high revitalization, high stability, and low-cost

[2] Clarification of physical and chemical mechanism of a hydrogen storage material and material searches
- Clarification of occlusion and discharge of hydrogen molecules in a hydrogen storage material, and accompanying deterioration mechanisms
- Search of hydrogen storage materials with high storage density and lower energy for the storage and discharge

[3] R&D on measurement technology for grasping behavior of system configuration materials
- In-Situ visualization techniques for observation of behavior of the hydrogen ions, water molecules, catalysts, carriers, and electrolyte films
- In-Situ measurement techniques for observation of storage and discharge

behaviors of hydrogen storage materials

Since the hydrogen can be produced from non-petroleum fuels such as natural gas and coals, and renewable energy source such as biomass, the oil dependence in the transportation sector can be reduced. In addition, the hydrogen energy system is thought to be applicable to a wide various fields including fuel cell powered vehicles, home-use hot-water supply and power co-generation systems, mobile device power supply, renewable energy storage, and so on, and its practical impacts on the society would be tremendous. A practical hydrogen energy system can be achieved only after development for practical use is made based on the knowledge obtained by the above R&D.

## 16. Ultra Lower Power (ULP) Technology【Executive summary in English】

Along with the development of information society, numerous high-performance information devices have been networked and used in anywhere in the society. With the great development of systems and devices in recent years, the power consumption has also reached to the level unable to ignore. As a result, the issue of the power consumption has been focused on very often. On the basis of this situation, one of the important research themes we have to work on strategically and comprehensively in the information communication field is "Ultra Low Power." It is an extremely significant research in a variety of fields including the protection of natural environment, stimulation of economy, improvement of industrial technologies, and realization of safe and secured life environment.

Although intensive research effort is made for the realization of low power consumption devices in this field, it cannot be said that the research activity is not sufficiently made in the “upper layer” such as system and software. From such viewpoint, this strategic project proposes a hierarchical R&D aiming at "Ultra Low Power." The outline is as follows:

1. The R&D on "Ultra Low Power" is promoted by integrating all the layers such as system/software, architecture/VLSI (Very-Large-Scale Integrated circuit) design, and circuit/device.

2. The research themes include a wide range of technologies as: the system technology for providing the service quality of the information system that would be required by the networked society of 10 years from now with the minimum power consumption; or the control technology for adaptability managing the quality level in order to provide the service required with energy available in the given environment.

3. Aiming at epoch-making low power consumption. For example, a project lasting about five years is carried out and setting the goal for the power reduction at one tenth for each of the three layers (one thousandth in total) as the system/software, architecture/VLSI design, and circuit/device.

4. A project should be carried out under a strong project manager with the awareness

of time base and involving the researchers of various fields.

5. The technology to be employed differs depending on the target level of the power consumption as: watt or higher (HPC: High Performance Computer, MPU: Micro Processor Unit); milliwatt level(portable and digital devices); and microwatt or less (sensor net/medical use). Japan has advantages in technology in the milliwatt level, therefore, we propose to start with the research on the milliwatt level first, and then expand the result to the other levels.

## 17. Development Scenarios and Basic Technologies in Asian countries 【Executive summary in English】

Many Asian countries are now rapidly growing, but their development depends on mass consumption of resources and has negative effects on environment, thereby leading to various problems such as destruction of nature because of industrialization and of population concentration in urban areas, increase of CO2 emission, air and marine pollution by harmful substances, pollution and shortage of foods and water, mass waste generation, rapid increase of oil prices, and so on. These problems are seriously impacting on environment and economic growth in not only the home country but also the neighboring countries and even the rest of the world. To cope with such problems, an alternative development scenario should be prepared as well as basic technologies for realizing it.

Then, for the solution of these global environment and energy problems, common interests of Asian countries, and sustainable development in Japan and other Asian countries, following researches should be carried out in cooperation with Japan and other Asian countries systematically and continuously:

[1] Research on sustainable development scenario of Asia
[2] Research on technology for advanced use of biological resources and ecosystem services
[3] Research on industrial and social infrastructure technology for resource conservation and minimizing environmental impacts
[4] Research on environment protection technology using ecosystem function and so on,
[5] Research on sophisticated environmental assessment technology
[6] Research on standardization of technology

For promotion of these researches, utilization of research resources in each country and cooperation with existing international joint research project should be promoted. As a measure of agreement between each country and systematic and continuous promotion, a joint research organization with the following functions, the Sustainable Asia Research Organization, should be considered to establish.

[1] A function as a joint research base for a development scenario and so on

[2] Human resource development and exchange
[3] Construction of information networks and databases

As China being the primary trading partner of Japan, Asian countries have become more and more significant for Japan as manufacturing bases as well as markets. It is significantly valuable for not only the government of each country and the local public but also for related companies to share the safety, environmental, and industrial standards taking account of Asian situation as an Asian standard, and to grow the standard as the global standard originated from Asia.

In addition, since the Asian region is a reservoir of biodiversity and biological resources, technologies can be expected to create and lead to science and technological innovation such as clarification of the function and mechanism of biological organisms and ecosystem, development of an assessment technology, new biochemical processes, and discovery and utilization technology for useful resources.

## 18. Future Biomass Energy System Base Technology【Executive summary in English】

A research and development strategy is proposed for fundamental technologies of growing and utilizing biomass, which are essential to reduce greenhouse gas emission and fossil fuel consumption in the future.

Biomass is hydrocarbons accumulated in plants and animals, mainly composed of carbon solidified by solar energy. In other words biomass is a form of solar energy fixed in living things. As long as reproduction is secured, it does not increase carbon dioxide content in the atmosphere, and is considered as carbon neutral. It is effective measure for reducing greenhouse gas emission as well as for saving fossil energy resources as long as the sun exists.

The energy potential of biomass in year 2050 is estimated as some half of the total primary energy consumption of the world in year 2000. Expectancy for it is high. The United States, European countries, and some of the other nations are moving toward higher utilization of biomass. However, both the diffusion and energy efficiency of biomass energy systems are low, and the potential has not been fully exploited. In Japan, especially, though biomass energy potential accounts for several percent of the primary energy consumption, only a little over 1 % has been actually utilized so far.

Japan is in serious need for utilization of biomass as a heavy importing country, who depends highly on foreign natural resources. Yet, the action for biomass utilization is far behind these countries, mainly due to small domestic potential of biomass supply and high cost to produce and collect biomass. It is essential, in order to cope with the worldwide shift toward biomass energy, to form a strategy in view of utilization of overseas biomass and to promote research and development of advanced technology.

A strategic workshop for projecting future science and technology titled "— R&D subjects for spreading and advancing biomass energy systems —" has been held to elucidate the contribution of biomass energy to cutting greenhouse gas emission and saving fossil energy consumption, and measures to maximize it.

Three objectives; ① to increase growth rate of biomass, ② to diff use the biomass energy system, ③to improve the energy efficiency in biomass energy systems, have been set. With attendees from industrial, academic, and governmental organizations, who have specialty in systems technology, nurturing or conversion of biomass, waste processing and so on, the discussion has been conducted for two days. On the first day, the issues relevant to the systems technology have been discussed. The second day, which was two weeks later, was planned for debates on element technologies in the system. Since it was difficult to examine the importance or priority of R&D subject without considering influences of social, economic, and political conditions, these conditions as well as technologies were taken into the scope of the workshop.

The workshop has produced a long term national vision in which;

・ Biomass sector is to be established as a key industry based on market principle, and
・ The development and resource security in Asia are to be secured through internationally well balanced utilization of biomass in the region.

The scenarios, action items, and R&D subjects to bring about the vision have been proposed as well, out of which fundamental R&D subjects for build a basis to increase biomass energy contribution dramatically have been extracted, and the following target has been established:

【Specific Target】

To develop fundamental technologies for increasing growth of biomass, improving energy efficiency and spreading its use, which are required for biomass energy to contribute in reduction of greenhouse gas emission and fossil fuel consumption, and to form a viable key industry for supply and use of biomass. As more specific examples, the following technologies are aimed at;

① Breed improvement technology to increase growth rate of energy crops, or to raise them in unsuitable land for cultivation such as desert or coastal lagoon,
  （a）Elucidation and manipulation technology of genes related to growth rate or tolerance to environment
② High efficiency production technology of liquid fuel from materials difficult to decompose such as cellulose or lignin,
  （a）Biochemical conversion technology to convert cellulose to sugar, and high activity enzyme
  （b）Thermochemical technology to control yield composition, and to refine product gas
③ Labor-saving technology for biomass energy system,
  （a）Monitoring and tracing technology for cultivation and collection of biomass
④ Durability improvement technology.
  （a）Corrosion resistant material, technology for prevention of stain deposition and/or self cleaning

## 19. Promoting of Basic Research on Preemptive Medicine using Self-Repairing – A Future of Regenerative Medicine Research 【Executive summary in English】

This strategic proposal aims to promote basic research that helps achieve preemptive medicine, by which clinical conditions are predicted with biomarkers and early intervention can be made; arguably one such strategy is to specifically focus on the self-repairing capacity of human cells that enables an innovative medical technology -“Preemptive Medicine using Self-Repairing”-.

Japan faces the issue of rapidly aging population combined with the diminishing number of children alongside the increasing the nation's total medical and care service expenditures. The latter came up with almost the same level of tax revenue of the nation. Therefore it is critical to reduce medical cost and to enhance the nation’s healthy life-span whereby the aged can play a major productive role in the society. This cannot be achieved without medical technologies that help strike a right balance between therapeutic efficacy and appropriate medical cost.

In general, the more the state of diseases progresses, the less therapeutic efficacy can be expected, resulting in the increase in medical cost. In this view, in 2010, Center for Research and Development Strategy (CRDS), Japan Science and Technology Agency (JST), made a proposal on the new medical concept - preemptive medicine - with a view to predicting clinical conditions by using biomarkers and enabling early intervention both against the onset of diseases and the progression of the state of diseases.

The reality is that it is difficult to completely prevent all possible disease of every single individual. Therefore, a possible blue print of future medicine is that regenerative medicine provides alternative therapeutics for patients whose clinical conditions became severe at irreversible phases even after preemptive medicine is performed. However, our analyses on current technologies of regenerative medicine indicate that under the current technologies, only in limited cases such as epidermis, cornea, and cartilage, recipients’ tissues can be replaced for functional substitution by cell therapy. Instead, what we currently have is technologies that can give indirect therapeutic effects to targeted patients’ own cells (endogenous cells) by humoral factors secreted from transplanted cells. In this process, the more the state of diseases progresses, the less therapeutic efficacy will be expected due to the decrease of the capacity of self-repairing of cells. On the other hand, interventions of current regenerative medicine are made at very late stages of clinical conditions. Theoretically, if earlier interventions of regenerative medicine become possible, much higher therapeutic efficacy would be expected. However, it is technically difficult with current technologies. One of the reasons is the lack of understanding of functional mechanisms as well as safety and efficacy of cell therapy. Therefore, regenerative medicine (cell therapy) can be considered as a last resort of therapy when others are ineffective but not ideal to use it from early stages of clinical conditions. If those mechanisms are uncovered, early interventions would be possible and even cell therapy would be replaced with other therapeutic approaches such as chemicals and biological drugs. Such change will also be important in terms of reducing the expensive cost of cell therapy.

We hereby propose a strategy to promote basic research that helps enable preemptive self-repairing medicine" (Figure 1). Our aim is to achieve affordable and efficient therapies by shifting intervention points from later phases where current regenerative medicine is expected to play a major role, to early phases by preemptive self-repairing medicine.

**Concept of "Preemptive Medicine using Self-Repairing**

The term "preemptive" in this proposal indicates that prevention not only against the onset of diseases but also the progression of diseases. The term "self-repairing" indicates that the functional regeneration of tissues through the intervention on recipients' own cells. Therefore, the concept of the latter is not limited to that of stem cell research. In fact preemptive self-repairing is a new medical concept which helps predict clinical conditions by using biomarkers, and prevent the progression of diseases by utilizing the self-repairing capacity of recipients' own cells.

In order to achieve preemptive self-repairing, three major strategies of basic research are proposed.

**Strategy 1：The establishment of interventional concepts**
**Strategy 2：The development of the diagnostic technologies for the early intervention**
**Strategy 3：The development of intervention technologies**

In Strategy 1, molecular mechanisms of self-repairing in regenerative medicine or other clinical cases are uncovered and interventional concepts are developed. In Strategy 2, biomarkers and diagnostic systems are developed to identify right timing of interventions. In Strategy 3, therapeutic technologies, such as self-repairing accelerating/inhibiting substances and drug delivery systems, are developed by utilizing what is achieved by Strategy 1.

This proposal targets aging-associated diseases, including amongst others, cardiovascular, cranial nerve, kidney, endocrine, liver, digestive, pancreas, auto immune, and musculoskeletal diseases. We believe that achieving "preemptive self-repairing medicine" contributes to realize a healthy aging longevity.

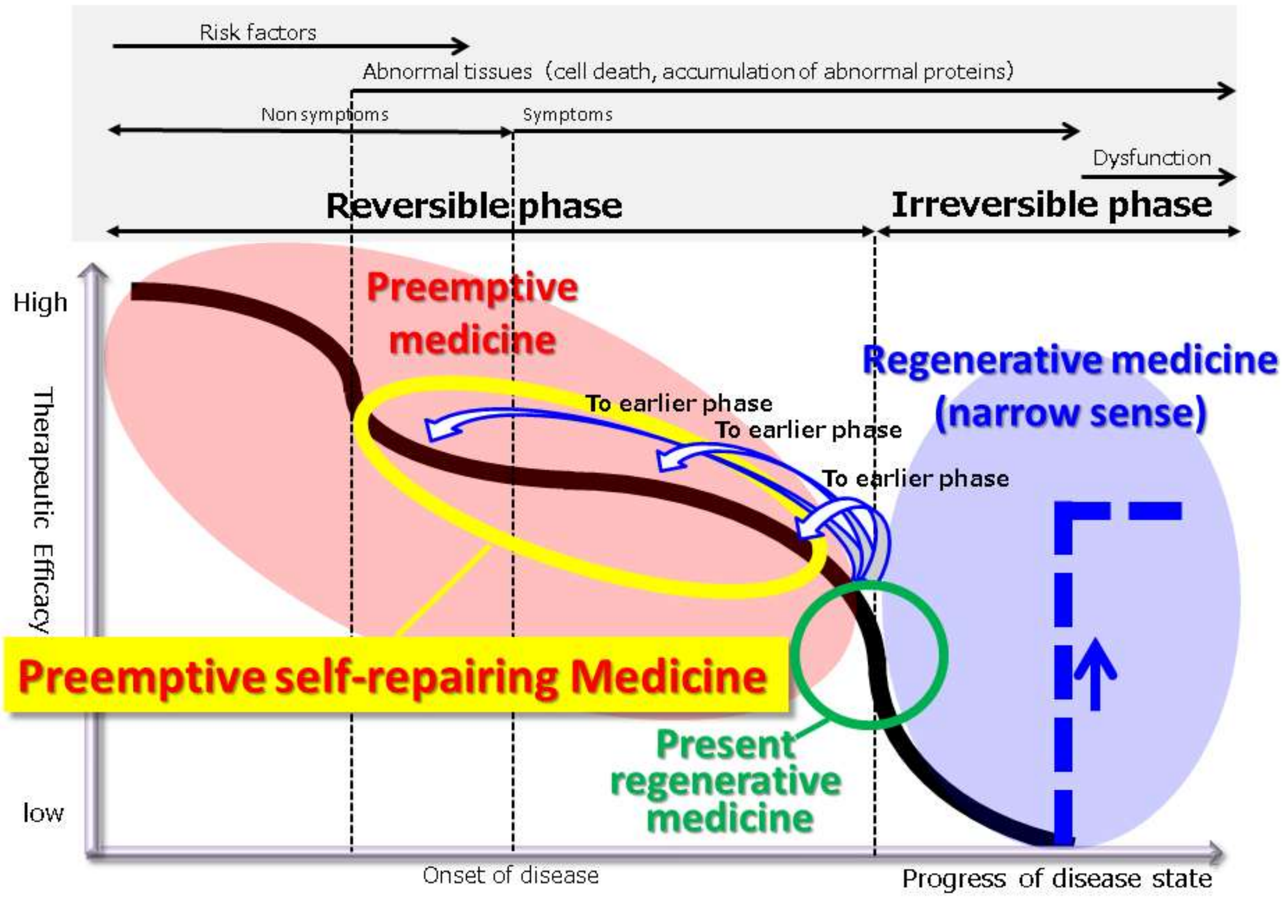



**Figure 1 The concept of "preemptive self-repairing medicine"**

The term "Preemptive Medicine" here indicates a medical concept, including not only prevention/delay against the onset of diseases but also the progression of diseases (red area). One the other hand, "Regenerative Medicine (narrow sense)" aims to achieve functional recovery of heavily damaged organs or tissues by transplanting cells, which are cultured outside of a recipient's body (blue area): The latter does not include the indirect therapeutic effects to targeted patients' own cells (endogenous cells) by humoral factors secreted from transplanted cell(self-repairing). In "current regenerative medicine”, some enable “regenerative medicine in the strict sense” and others do “self-repairing” (circled in green). “Preemptive self-repairing medicine” is the approach to achieve higher therapeutic outcomes and reasonable cost by advancing the interventions of the “current regenerative medicine” to earlier clinical phases (circled in yellow).

## 20. Strategy for Integration and Application of Databases in the Fields of Life Science and Clinical Medicine【Executive summary in English】

Information from data analysis leads to a new discovery. Recently, the need for analysis of more enlarged databases or across multiple databases has increased. Those trends have created a new stream of data science called big data.

Global trend for personalized medicine is remarkable. It has begun to utilize personal genome analysis for medical treatments. Some genomic epidemiology studies require huge size of data from tens of million people. If personal genome information is incorporated with such studies, there are technical challenges for large-scale, high throughput analyses in a secure, efficient, and precise manner against big data.

This proposal, entitled "Strategy for Integration and Application of Databases in the Fields of Life Science and Clinical Medicine", addresses the next-generation strategy for integrating accumulated data from previous database projects in Japan. Databases of basic science, clinical medicine, and personal genomes should be integrated and analyzed to produce innovation in personalized medicine and life science. Sensitive bioinformation must be carefully handled. This proposal balances privacy protection with public benefits from data science using personal, medical, and genomic records.

This proposal consists of three propositions: (1) data standardization, legislation, and infrastructure for information sharing, (2) development of innovative technologies for processing or analyzing life science data and medical records, and (3) human resources development for promoting research and development in bistatistics and bioinformatics. Implementing these propositions together will bring outputs such as realization of the personalized medicine. We recommend to carry out this proposal rapidly, as people can realize its outcomes such as promotion of public health.

◆ Proposition 1: Improvement of infrastructure for information network
- Data standardization promoting data exchange
- Legislation balancing privacy protection and data utilization
- Establishment of the steering committee for data network via cooperation among all relevant governmental agencies

◆ Proposition 2: Research and development in data processing and analysis
- Promotion of cutting-edge data science in the fields of medical and life science
- Organization of data centers that can manage sensitive information in security

◆ Proposition 3: Human resources development

- Continuous employment of engineers operating stable information services
- Development of human resources in biostatistics and bioinformatics

## 21. Social Ecological Model - Promotion of Experimental Study in Local Area Based on “Biodiversity Science for Science Policy【Executive summary in English】

Human socio-economic activities bring about the loss of biodiversity, and ecosystem and living organisms fail to adapt and cope with this environment. As a result, we face endangered ecosystem services (human benefits from a multitude of natural resources and processes). So we propose strategic research conducting the creation of “Social Ecological Model,” which focuses on conserving biodiversity for the construction of a sustainable society.

“Social Ecology” is a concept concerning a sustainable society where human live symbiotically with nature. This ideal society would be realized by nurturing the relationship between human and nature, and it is important that habitants and developers utilize natural resources moderately. The “Social Ecological Model” is an experimental research for science policy focusing on biodiversity and we propose comprehensive strategy to build a sustainable society through policymaking based on scientific knowledge.

The reason why we propose strategic research on policymaking concerning biodiversity science in this report is accumulating and integrating of ecosystem information on biodiversity worldwide, and there is a rise in expectations regarding the conservation of ecosystems. In response to the movement towards conservation, many international sectors are discussing whether scientific knowledge is useful in policymaking or not. We feel it would be difficult to use scientific knowledge for policymaking because of the difficulties in the quantification of social and economic outcome and in a consensus of the stakeholders. Considering this, we attempt to conduct R&D on the “Social Ecological Model” and aim at creating a model that will define the continual relationship between human and nature.

The R&D that we propose here involves (1) the development of a policy tool, (2) drawing up policy scenarios, and (3) policy evaluation and the progress in environmental management technology. The first point involves the construction of prediction models for biodiversity and ecosystem services. The second point involves identifying problems using the policy tools and proposing solutions utilizing technologies, legislation, and systemization. The third point involves policy evaluation based on science and development of technologies to solve relevant problems.

As a part of this research, we hope to collaborate with scientists, local residents, developers, policy makers, and NGO/NPO workers. In many cases, the participation of the local residents will bring them scientific understanding of biodiversity and make them aware of its value and ways to use it sustainably. In addition, the collaboration with local residents will help researchers to collect on site habitat information on biodiversity and will increase consensus forming on various issues to make policy implementation easier.

## 22. Preparedness Framework and Its Governance of Dual Use Research of Concern for Promising Progress of Life Sciences【Executive summary in English】

The risk of potential dual use of life science researches has recently increased, especially due to the progression of molecular biology.

This proposal targets life science researches and suggests develop strategies to prevent dual use and establish the governance system for the development of life science to contribute, in a sustainable way, to promote global health and protect global environment as well as those of Japan.

This proposal is intended for the offices and ministries of governmental agency, funding agencies, academic societies, research institutions, and research personnel, laboratories. This proposal gives priority to establish the framework in which nationals could benefit from the smooth implementation of life science research and development conducted by stakeholders above, and it does not suggest for nationals, who are final customers of life science research outcomes as well as potential victims of misusing those, any concrete propositions requiring efforts to prevail.

The followings are our proposals of actions and governance system to prevent dual use.

1. Offices and ministries of governmental agency
    - Developing and sharing uniform policies of Japan to deal with dual use and sharing it
    - Rapid capture of research projects with dual use concern, sharing the information about those projects among offices and ministries, and establishment of appropriate prior evaluation and progress management of those projects
2. Research personnel and laboratories
    - Awareness of dual use
    - Experiment (procedures, methods and results) management with considering biosafety and biosecurity
    - Execution of "accountability as experts" at delivering or pressing-show outcomes.
3. Research institutions
    - Conducting "enlightenment, training and education" of dual use for anyone

who engage in researches (including students at universities)

- Development of management system inside of institutions to guarantee biosafety and biosecurity
- Providing opportunities for science media to obtain the literacy of dual use

4. Academic societies

- Developing policies to deal with dual use as expert communities
- Enlightenment of experts in the communities according to the policies, establishment and compliance of original guidelines to prevent misuse, organizing the peer-review system of academic journals
- Providing opportunities for science media to obtain the literacy of dual use

5. Funding agencies

- Aligned with governmental agencies, developing system of detecting research projects with high probability of dual use, evaluating them beforehand and managing the progress of those projects
- Verifying risks of dual use in establishing new research projects and planning strategies to prevent misuse
- Through funding activities, cautioning researchers and research institutes to plan strategies preventing misuse, and monitoring and evaluating the state of implementation of those strategies
- Providing opportunities for science media to obtain the literacy of dual use

The proposals above will promote awareness of dual use in a field of academic research and technology development of a wide range of life science. And biosafety and biosecurity are more enhanced at the level of research personnel or research institutions. In addition, as various stakeholders provide multilevel opportunities of enlightenment and training of dual use, academic researches will bring their outcomes implemented more precisely and honestly. At the end, through the fulfillment of researchers' responsibility for explaining research outcomes to nationals via science media, it is expected to contribute to achieving peaceful lives of nationals, the final beneficiaries of life science researches.

## 23. Integrative Promotion of Nation-wide Infection Control −Vaccination and Epidemiology−【Executive summary in English】

The strategic initiative “ Integrative Promotion of Nation-wide Infection Control − Vaccination and Epidemiology − ” is a proposal package for solving health-related social issues associated with infectious diseases. This proposal includes research and development (R&D) strategy to overcome infectious diseases, social implementation of those R&D results, and practical operations of measures whole related activities.

Occurrences of serious infectious diseases continue to be reported around the world. Although the mortality rate of infectious diseases has significantly dropped in Japan owing to the improvement of the accessibility to medical care, nutritional status, public sanitation and so on, Japanese people are still threaten by infectious diseases, such as influenza and tuberculosis. On the other hand, an infectious disease appearing in one country or region can now quickly spread around the world through the global, advanced transportation systems. Nowadays, the Japanese public is also facing emerging threats of artificial infection risk including misuse and dual-use of biological materials (biohazards, bioterrorism, etc.) which are keenly recognized at the global level but not in Japan. Countermeasures against such emerging threats are not effectively prepared in Japan. Considering these circumstances, Japanese nation is still vulnerable to infectious diseases. Therefore we propose accelerate development and industrialization of vaccines, practical operation of epidemiology against infectious diseases, and enhanced transmission of epidemic information. It is also urgent to pursue measures underpinned by scientific knowledge and technology to minimize health problems associated with infectious diseases from a viewpoint of a long-term national strategy.

Based on the situations described above, the Center for Research and Development Strategy (CRDS) at Japan Science and Technology Agency (JST) investigated the current status and issues of R&D and social implementation for controlling infectious diseases in and outside of Japan, and had discussions with experts from industries, academia and government. In conclusion, we propose that the promotion package of following three disciplines for reducing risks associated with infectious diseases.

- Strategic imperative 1: “Promotion of Research and Development” ・・・(vaccines and adjuvants, etc.)

- Strategic imperative 2: "Establishment of Infectious Disease Epidemiology"・・・(collection and organization of domestic and overseas information, samples, etc.)
- Strategic imperative 3: "Social Implementation" ・・・(analysis and distribution of information about infectious diseases, assessment of research results, and social implementation of measures against infection diseases that are supported by scientific evidence, etc.)

It is a globally-shared view that vaccines are an extremely important factor to protect not just individuals but the entire society against the threat of infectious diseases.4 In recent years, increasing attention has been paid to adjuvants, which are pharmacological agents and can activate the effect of vaccines, making vaccine administrations more efficiently and effectively. For Strategic imperative 1, collaboration should be made by industries, academia and the government to form a target-oriented R&D consortium with paying attention to dual-use problems (use of research results for military purposes). The consortium should facilitate the quick development of effective and safe vaccines and adjuvants for the infectious diseases that are identified as targets for R&D based on results of comprehensive survey of domestic and international epidemiological trend and social needs. It should also promote a research that takes interdisciplinary approaches, with an aim to create innovative seeds from a mid-to-long term perspective.

It is requires for strategic imperative 2 to provide various information needed for R&D and the social implementation of infection control. Academia and the government should promote strategic imperative 2 through the identification of transmission routes/hosts and collection of samples by academia as well as rapid and accurate infectious disease surveillance (investigations/ monitoring) by relevant governmental agencies. At the same time, the database infrastructure should be reconstructed through accumulation and compilation of the information about various infectious diseases.

For Strategic imperative 3, Academia and the government should promote streamlining and improving the information networks of academia and relevant governmental agencies, which distributes information related to infectious diseases both under normal and emergency conditions. Several issues should be clarified to build up the information networks, for examples, what is the best channel, what is the proper information content, who is the best distributor, and so on. Furthermore, collaborative efforts should be made across academia, industries, the government, etc. to carry out health technology assessment on vaccines, including medical, social and economic aspects.

In case of pandemic, immediate action to prevent further spreading is required. Therefore we propose focus on suppressing the pandemic in order to quickly develop the vaccine, produce it in sufficient quantities, and make it available to the public. In normal situations, it is important that each of above strategies are continuously pursued with a long-term perspective, and only if they are steadily implemented under normal conditions do they become capable of quickly responding to an emergency situation.

When developing a vaccine or adjuvant for a particular infectious disease, the time frame for Strategic imperative 1 may vary widely depending on the target disease, how much progress the research is making, and how great the potential threat of the disease (a pandemic) is or will be to the health of the Japanese people. For example, when a pandemic occurs, it is desired that the development process be completed within several weeks to several months. However, for a disease that can potentially cause a pandemic in the future, the development is expected to be completed within ten years, including the time required for the clinical study.

This initiative should contribute not only to mitigation of risk associated with infectious diseases in Japan but also to an innovation in Life Science field through the development and global launches of new vaccines and adjuvants that can meet medical needs in Japan and overseas. And more, this initiative accelerates enhancing infectious disease epidemiology, which serves fundamental information for R&D activities, as well as creating new interdisciplinary fields for vaccine R&D. Furthermore, this initiative also aims at establishing the frameworks capable of responding to a pandemic emergency by facilitating the quick development of a vaccine in Japan and supplying it to the public in sufficient quantities, which will help assure the safety of the nation.

## 24. Integrative Elucidation of "Cellular Communities" for Disease Control 【Executive summary in English】

The strategic program "Integrative Elucidation of Cell Communities for Disease Control" is a research proposal to clarify disease mechanisms with an integrative approach to elucidate the formation mechanisms of "cell communities" that influence the status of biological tissues. In this proposal, the term " cell communities" is defined as one of the variable cell populations, responding to stimuli from changes of intracellular and extracellular conditions including cell-cell interactions.

As many as 200 types of cells constitute an organism, and highly diverse biological phenomena occur through the interactions among these cells. This means that complex interactions among a variety of subpopulations of cells may contribute to maintain the community of cells as a whole. By responding to changes in surrounding environments, such " sociality" of cells would be modified to maintain or disrupt organism homeostasis. In particular, a recent study has shown that healthy cells, which initially appear to be unrelated to a disease, can actually form an interdependent relationship with malignant cells and influence the formation and maintenance of the " cell communities" in disease states （see the column in chapter 1）. One can expect that further elucidation of the formation mechanism of communities interwoven with a wide variety of cells would contribute with higher efficiency to the early detection and treatment of disease. There have been technical problems to investigate and reconstruct the formation mechanisms of the "cell communities" in disease states. However, new technologies to overcome these problems have emerged in recent years. By rapid development of emerging technologies, as well as the integration of findings in the specialized fields of basic research for detailed understanding of life, one can aim to elucidate the "cell communities" by effectively integrating these technologies and detailed understandings. A full understanding of the "cell communities" may enhance comprehension of the mechanisms by which diseases appear and advance in organisms. It may also lead to the improvement of medical cares, the development of science and technologies, and the establishment of industrial competitiveness for Japan.

This proposal promotes research activities that will further clarify disease mechanisms. We aim to engage basic medical technologies generated by research on the "cell communities" into practical use.

(1) Research for understanding the "cell communities" in disease states:

- Develop analytical technology for elucidating the structure and functionality of the "cell communities."
- Analyze disease mechanisms triggered by changes in the state of the "cell communities."

(2) Research for the reproduction of the "cell communities" that occur in disease states:

- Develop technologies that cultivate reproductions of the "cell communities" with disease properties.
- Develop animal models that reproduce the "cell communities" with disease properties.

As a result of the advancement of above-mentioned research, one may be able to expect the development of prevention and treatment technologies with much higher efficiency, in addition to the better elucidation of disease mechanisms.

To promote this proposal, it is strongly encouraged to form a highly collaborative research system (described below) to elucidate the mechanisms underlying individual disease through the elucidation of the "cell communities."

① "Coordination of different research fields" teams: investigators from the diverse and specialized fields of life science research share the fundamental knowledge.
② "Fundamental-and-clinical medicine coordination" teams: share knowledge regarding the clinical pathology of disease and corresponding knowledge in basic research.
③ "Medical-and-engineering-field coordination" teams: researchers in medical and engineering fields collaborate to develop technology by matching needs and seeds in both research fields.

These highly collaborative research will accelerate the development of basic technologies that serves as a platform for the integrative elucidation of the "cell communities." Depending on the status of progress in each team, feasibility studies and pre-clinical trials may start under academic-industrial partnerships with pharmaceutical companies and/or medical device manufacturers, based on the basic technologies from the individual teams. At the same time, the following research infrastructures necessary to propel research on the "cell communities" will have to be established.

① Establishment of an institute for integrating knowledge on the “cell communities” from various research fields in medicine, science, and technology to strengthen the foundations of research.
② Trainning human resources with a long-term perspective.
③ Outfitting libraries and databases for human specimen that can be accessible for both academic and industrial researchers.

In addition to developments in science and technology through cooperation across the fields of life sciences, medicine, and engineering, this proposal will empower industrial competitiveness of Japan by solving unmet medical needs, reducing medical expense, and creating new medical supplies and diagnostic systems.

## 25. Homeodynamics -Understanding and Control of Spatio-temporal Dynamics between Neural, Endocrine and Immunological Networks 【Executive summary in English】

We propose research promotion of homeodynamics as the dynamics of homeostasis in this strategic initiative. Homeostasis is one of the fundamental life phenomena. However, it is hard to get an integrated understanding of homeostasis because research in the fields of neurology, immunology, endocrinology, tissue repair, and stem cells is compartmentalized and complex, there are not adequate exchanges of information between these research fields, and the analytical methods, data utilizing technology and application of mathematical technology are still immature. An integrated understanding of homeostasis has thus been a problematic issue at the end of the 20th century.

In the 21st century, accumulation of genetic information in these two decades, advances in bioinformatics, and an increase in supercomputer performance open the way to simulation and modeling of a complex system like homeostasis.

In order to maintain homeostasis and protect the body from stress or diseases, the nervous and vascular systems are distributed throughout the body to form systemic structural networks. Through the vascular network, signal molecules （hormones, neurotransmitters and cytokines）and immunocytes are transported throughout the body to form local functional networks. We call such systemic structural networks and local functional networks "Networks of Networks."

Dynamic changes in homeostasis occur with time, through the life stages of development, birth, growth and aging. The homeodynamic "networks of networks" are spread throughout the body space. This initiative proposes that integrated homeodynamic research will provide a novel spatiotemporal understanding of homeostasis.

For the understanding and control of homeodynamic "networks of networks," the research involved in this initiative is as follows.

1. Understanding of the homeodynamic mechanism

1）Quantitative study of stress, stimulation and the reaction of the body

2）Modeling study based on the quantitative study

3）Experimental study of the model

2. Logical research for control of the homeodynamic research
3. Translational research for the application of medical treatment

Since both the biologist handling a wet specimen and the informatician handling dry data join forces and cooperate to perform this research, the ideal interdisciplinary organization of the researchers is that of a team, and the results of the research must be shared in the team to make or test hypotheses. The research manager of the teams shares the aim of an integrated understanding of homeodynamics by the team leaders, helps the teams cooperate, and manages the research centrally. The research manager needs strong leadership to conduct such interdisciplinary research.

The promotion of this initiative relies on the integration of fundamental and computational biology, and thus opens a unique new and unexplored research area. Since most diseases are the result of the disruption of homeostasis, an understanding of the disruptive features will lead the way towards a healthy life through the respective life stages of development, growth, and aging. The eventual goal of this study is therefore a "calm mind," "healthy growth" and "healthy aging." On the way towards the goal, the integration of homeodynamic research will introduce novel understanding for the view of life, and the application of research will contribute to the prevention and treatment of diseases, combination of medicine and safe medications.

## 26. Promoting Preemptive Medicine in a Hyper-Aged Society【Executive summary in English】

In Japan, with its rapidly advancing graying and low birth rate, it is anticipated that there will be a rapid increase in medical costs coupled with remarkable progress in medical technology and medical needs, and at the same time the need for nursing care will also increase. Furthermore, on the other hand, there has been a definite decrease in the number of working young people, and how to safeguard the elderly and their home life, as well as how to respond to a steep increase in medical costs, is becoming a major issue of concern.

Generally, diseases which deteriorate the health of the elderly and create the need for nursing care have genetic causes in the background and appear due to a long-term complex relationship with environmental factors. Consequently, it has been very difficult to identify the cause and mechanism of the disease. Moreover, these diseases are difficult to completely cure once they appear, there are many cases where the disease gradually progresses and results in serious complications, threatens the patient's life, and requires nursing care. The issue of how to deal with these diseases that accompany aging is of utmost importance in Japan, where the birthrate is declining and graying is advancing. Under these circumstances, calls have been made for the importance of prevention, but preventative medicine thus far has mainly taken the approach of identifying disease risk factors and getting people who are deemed to be high-risk to avoid them.

In recent years, advances have been made in research regarding the relationship between individual variation of the human genome and diseases, and gradually more is becoming known about disease-causing genes. Also, progress is being made in research on identifying how the environment during the fetal stage and after birth influences the onset and development of disease. In addition, it has been observed that in diseases accompanying aging, in many cases certain pathological changes have already taken place during the pre-onset asymptomatic phase. On the other hand, in regards to the biomarkers[3] which serve as an index for the development of disease, rapid advances are

[3] Biomarkers are indictors to objectively grasp the physiological condition of a living organism, the progression of the disease, and the reaction to therapeutic intervention. In addition to the biological substances included in urine and blood, etc. (genomes, epigenomes, transcriptomes, proteomes and metabolomes, etc.), various indices are used, such as image scans like PETs, electrocardiograms, and bone density.

being made in research on biochemical findings such as proteins and RNA, and signs from imaging, etc as well. Due to such progress in life science, it is becoming possible to diagnose several diseases during the pre-onset asymptomatic phase (henceforth, the "pre-symptomatic phase"). Consequently, biomarkers, different from previous prevention methods, will be used to predict the onset of disease at high probability, and a new medical science which focuses on its target of therapeutical interventions at an early stage is expected to become a reality in the near future.

Taking the aforementioned background into account, this initiative proposes preemptive medicine as a new direction for medical science with the aim of diagnosing, predicting and treating disease with a high degree of accuracy in the pre-symptomatic phase even when there are no clinical symptoms and no abnormalities are detected in routine medical check-up, and furthermore, proposals for research and development issues based on this idea that should be taken up by the government at the earliest possible opportunity are summarized as the following four issues. Although there are some differences for each disease, basically, these issues are common to all diseases.

Issue 1: Identification of the cause and mechanism of disease
Issue 2: Search and discover candidates for biomarkers and seeds for treatment technologies
Issue 3: Narrow down the candidates for biomarkers and seeds for therapeutic treatment technologies and assess their safety and usefulness
Issue 4: Appropriate provision of preemptive medicine (giving the results of our research back to society)

Issue 1 is the foundation for all of the issues described above, and from the viewpoint of preemptive medicine it promotes genetic, molecular biological, biochemical, cell biological research regarding the development of disease, as well as various types of clinical research to understand the interaction of genetic factors and environmental factors, with epidemiological research, including cohort research in particular. In Issue 2, in order to narrow down the group of biomarkers, that enable us to diagnose patients in the pre-symptomatic phase and in order to assess the usefulness and safety (effects and side effects of drugs, etc.) of seeds that can be applied for a therapeutic intervention, we will thoroughly and systematically search for biomarker candidates and treatment technology seeds. Specifically, data obtained from "omics research" (genomes, epigenomes, transcriptomes, proteomes and metabolomes, etc.), imaging diagnosis such as molecular imaging, and epidemiology will be analyzed. In Issue 3, the reproducibility, usefulness, and safety of the biomarker candidates and treatment technology seeds will be verified. For this purpose, in human trial – namely clinical research – under scientifically acceptable conditions will be conducted on a large number of people. In Issue 4, we will conduct a scientific examination on advancing the propagation and establishment of preemptive medicine in society. As preemptive medicine means performing examinations and treatments on people who are in an asymptomatic state in which clinical symptoms have yet to appear, it is essential to deepen their understanding of its necessity. The methods in which the biomarkers and treatment seeds developed in Issue 3 will actually be used will be considered based on statistical, economic, and sociological analysis. As for the therapeutic tools, compliance (patient compliance with doctor's instructions), cost effectiveness, and possible side effects will also be considered. Furthermore, as a measure toward social acceptance, systematic and behavioral medical research will also be conducted to examine the improvement of medical literacy and behavioral modification, and examining how the costs should be shouldered, etc.

The aforementioned research will be promoted by many players: basic research centered on academia (mainly Issues 1, 2), applied research and development via collaboration between the private sector, academia and government involving industry (mainly Issues 2, 3), clinical research centered on hospitals (mainly Issue 3), and applied research by the national and local governments, academia, medical facilities, insurers, industries, NPOs, etc., in order to create acceptance and establishment of new medical technologies in society (mainly Issue 4). With this as the foundation to proceed effectively and efficiently, strategic collaboration with existing cohorts based on long-term vision and the design of new cohorts, as well as the formation of clinical research support centers should be promoted together. Furthermore, as the development and application of new medical technologies requires a comparatively long period of ten years, the timeframe of this initiative as a whole should be estimated at around twenty years.

As diseases for case studies for preemptive medicine, this initiative will take up Alzheimer's disorders, Type 2 diabetes, osteoporosis, and breast cancer, and organize the issues that should be engaged taking the present state of each disease into consideration. The details are as described in this document.

In conclusion, when the aforementioned preemptive medicine is made a reality, a new medical science entirely different from what has existed thus far will be born, and the development of various related medical technologies will give birth to large industrial profits. At the same time, if many people are able to lead long, healthy lives, not only will this result in a reduction in medical and nursing care costs, a high-quality life can be ensured, which is something of immeasurably great value. The advancement of preemptive medicine holds the promise of creating large social and public value in addition to industrial and economic value advocated by innovation. This value can be called the "fourth value," as opposed to the ones that accompany primary agricultural or natural products can be called the "first value," the ones that accompany industrial production can be called the "second value," the ones that accompany intellectual property rights can be called the "third value." This is because the fourth value will greatly contribute to people leading longer, healthier, and higher-quality lives.

## 27. Development of Cohort Design for Novel Health Risk Prediction 【Executive summary in English】

In order to have a healthy body until the time of death, it is extremely effective to identify some unknown factors that would affect health conditions for one's entire life such as stress and genes. Generically, it is considered that identifying these factors will establish the basis of developing technologies that would avoid and control health deterioration. In particular, we think that" individual genes"," development and aging", and" environmental factors" are important factors for developing new technologies.

Thus, we propose three research developments under the following subjects in this strategic initiative. These subjects are necessities of a research infrastructure for monitoring the above risk factors throughout one's entire life, and they also advocate a strategy of technical research required for integrating existing outcomes already obtained via cohort studies.

Subject I　Lifelong cohort study
Subject II　Quasi-lifelong cohort study by integrating existing cohort studies
Subject III　Study for risk factor and biomarker based on correlated analysis of several existing cohort studies

In Japan, several cohort studies based on the above viewpoint have already been attempted. However these studies are limited in many aspects, such as targeted age and type of disease subjects. Thus, many projects have been promoted in terms of infant stage, adolescence, and old age. On the other hand, in order to understand accurately the risk of health, we need to obtain biological and environmental information throughout one's entire life. However as indicated above, several cohort studies in Japan are limited in duration, thus we do not have any system for identifying the lifelong risk of health. In contrast to this, other countries (e.g. advanced countries) regard biological information as a" national asset" and promote a lifelong cohort study. For example, Britain established a system for monitoring risk factors of health deterioration over sixty years, and some countries conduct a long term cohort study by targeting 100,000 to 500,000 people by setting up a Biobank (facility for blood serum samples).

Considering the above awareness and trends in other countries, we propose cohort studies that should be promoted in Japan. Subject I is a lifelong cohort study that gathers biological, environmental, and clinical information over an entire Japanese life. Subject II is a cohort study that connects and analyzes existing cohort studies, and Subject III is a research and development (R&D) study that creates a fundamental technology for maintaining a healthy body. The importance of Subject I is as previously described. We promote Subject II because it is necessary for over 100 years to conduct Subject I and analyze its results. Subject III has already been carried out in some projects. However, there are hardly any projects on a correlated analysis between a biological factor expressed in the infant stage and health deterioration in an old age. In addition, we propose collaborative research studies with social scientists such as those involving the design of a lifelong cohort study, the formation of a social consensus, and the establishment of a follow-up system for a persistent study.

Conducting the above R&D study, we can expect many impacts, such as the establishment of Health Information Base. Using this base, we can also expect to create much knowledge of precaution and make considerable progress in basic research on the elucidation of life phenomena.

It is not sufficient only to promote individual researchers by the bottom up approach for constructing a research infrastructure targeting all Japanese people. We think that the government should construct a core facility for connecting several cohort studies, build collaborating systems between local governments and healthcare facilities, and also promote public understanding at the start of this initiative.

## 28. Research and Development of Human Cellular and Tissue Engineering for Clinical Development【Executive summary in English】

The strategic initiative entitled "Research and Development of Human Cellular and Tissue Engineering for Clinical Development" provides the research and development strategy to apply recent technological achievement of cell dynamics biology to regenerative medicine, transplantation immunology, and artificial organ technology, which would progress the innovative tissue and biomaterial engineering to reconstruct multi-cellular structure(s) for specific vital function of human organ(s) ready to implant in human bodies.

The research and development plan suggested in this proposal would deliver safer and high-functioning artificial organ(s)/tissue(s) to patients who have no alternative treatment. It would also expand treatment opportunity using organ/tissue implants, resulting in reducing medical care costs on the patients currently depending on symptomatic therapy, and also solving ethical and technological (including immunology) problems of organ donation between humans. Thus, promoting this research and development strategy would improve health progress the industrialization of life science technologies, and resolve the global pending issues of ethical, legal, social implications of organ transplant businesses.

Currently, various regulations and limitations associated with organ donation/ transplantation in Japan cause mismatch between the numbers of patients and donors of organ transplants, resulting in the shortage of organs for implantation. In addition, the number of patients who visit developing countries from developed ones for organ transplantation is increasing, which causes among poverty societies illegal organ trades or abduction and murder of children to retain organ supply for transplantation. Considering such situation, the sixty-third World Health Assembly of World Health Organization (WHO) adopted WHA63.22 on 21 May 2010, recommending each member country to develop a system for the altruistic voluntary non-remunerated donation of cells, tissues and organs in accordance with nation capacities and legislation[4]. This adoption suggests that each nation should make considerable effort to provide sufficient organ supply for transplantation within its own country. Because social need for the organ supply is quite urgent, technologies to make up artificial cells, tissues, and organs would be anticipated internationally.

[4] http://apps.who.int/gb/ebwha/pdf_files/WHA63/A63_R22-en.pdf

In this proposal, we recommend the following three research and development projects to progress technological basis and elements of three-dimensional tissue engineering followed by the clinical development and industrialization.

- Development of cell and tissue engineering technology to reconstruct an organ or develop multi-cellular structures which retain vital function of the given organ
- Development of manufacturing process of an established artificial organs and multi-cellular structures
- Establishing immunological approaches to improve graft survival rate including development of useful indicators and measurement technology

The goal of the first project is to establish innovative technological basis manipulating various cells and biomaterials for making artificial organs and multicellular structures. The second project aims the establishment of well-qualified manufacturing process applicable to mass and stable production. The last one aims molecular-level immunological control system, in terms of immunological tolerance and development of indicators which measure the manufacturing processes, as well as a simulation system for the patient's vital condition.

Regarding the research team structure for these projects, it is required that each researcher (or research team) in the team set his/her goal and share his/her achievements across members. And it is recommended that both academic and clinical institutes are involved in the projects and integrate elemental technology for clinical science-oriented, goal-oriented research and development. Further, to facilitate clinical development which connects clinical science achievements to social benefits, it is important to keep close contact with both industries and competent authorities throughout the projects.

In this initiative, 10 years are estimated to establish an initial manufacturing process of multi-cellular structure with specific vital function(s), and biological/medical progress for successful engraftment of the implanted artificial structures, which includes pre-clinical trial. Additional 5 years may be required to establish an efficient manufacturing process as well as to pass clinical trials, so that the estimated achievement period is at least 15 years.

## 29. Challenges for Life Innovation【Executive summary in English】

Our country has moved into a hyper-aged society, such that we are seeing soaring medical costs and greater medical needs as the size of the elderly population increases. While the rest of the world is also experiencing an aging trend, emerging countries are seeing an increase and diversification in their medical needs. Consequently, the healthcare industry's move into international markets is a trend being seen in the advanced countries. The field of medicine as an industry is expected to increasingly develop in the future due to these increased and diversified medical needs on a global scale.

The factors such as the remarkable progress in biotechnology have led to great advances in medical technology. The advances in these technology will also lead to the revitalization of the medical industry. Our country faces, however, a range of problems that hinders any revitalization, resulting in lower growth of the overall medical industry. To get past these current circumstances, it is necessary to strongly promote technological innovation in the medical, care, and health fields, that is, strive for "life innovations." These life innovations can be expected to make it possible to provide the most up to date medical services in a safe and timely manner and with the healthcare economic validity, while the medical industry can be expected to be not only a growing and leading industry but also act as a driving force for future higher economic growth and job creation.

To realize these life innovations, it is necessary to establish and improve both systems and research environments. The government will be required to take a major role in bringing this about, in addition to government-industry-academia collaboration. Therefore, we recommend that the government apply the following five measures.

(1) Development of human resources to be involved in clinical research
Development of human resources required for translational research and clinical research that form the foundation of life innovations, establishment of systems for assessing clinical research results etc., and the introduction of clinical research fellowships

(2) Further promotion of clinical research and reinforcement of research support systems
Establishment of clinical research institutions and assist centers (clinical research assist center etc.), promotion of basic research that contributes to the immediate implementation of clinical research, information exchange and mutual understanding

between regulators and clinical research institutions/assist centers through personnel exchanges, and reinforcement of the registration system for cancer and other major diseases

(3) Reformation of regulation
Unification and reinforcement of review and approvals systems for medicinal products and medical devices etc. by the introduction of a Japanese version of the IND system on the basis of the creation of a medicines agency as a government organ (a Japanese version of the FDA)

(4) Establishment of office-ministry collaboration
Efficient use of research funds and infrastructure by revitalization and reinforcement of the existing Health Research Promotion Council, and the development of comprehensive policies for clinical research and support for the policies

(5) Support for bio-ventures and formation of special zones
Introduction of a Japanese version of the SPA system, establishment of a system for securing research funds and support for the system by the Industry Innovation Organization etc., the formation of special zones, and the reform and deregulation of existing systems

## 30. Technology for Genomic Design of Environmentally Adapted Crops 【Executive summary in English】

Climate change is one of the most important issues in our present and future lives. It is concerned that the global and regional climate change will negatively affect plant growth, including crop production, not only in Japan but also in other major agrarian regions of the world. Furthermore, conventional agricultural activities cause high levels of energy consumption. We, thus, must shift our farming methods from the conventional ones to alternatives.

In response to the concern mentioned above, plant scientists and engineers are required to conduct R & D to create environmentally adapted crops by applying the latest findings. Specifically, a cutting-edge research target is the integration of various levels of information, from genotype to phenotype, within a plant in order to understand its response to the environment in the field. Although such R & D is mainly conducted by enterprises and research institutions in the US, Europe and Australia, Japan also has the potential to tackle the issue by using our knowledge of basic plant science and engineering technology.

Therefore, CRDS proposed the R & D Initiative“ Technology for Genomic Design of Environmentally Adapted Crops”, which is intended to strengthen the implicit function of plants. The genomic design technology is an advanced technology that correlates the molecular information of a plant genome with phenotypic output of the plant responding to the environment of the field. In this initiative, the following three complementary research issues were proposed.

1、Integrated quantitative analysis of the mechanism of the plant ′s response to the field environment
2、Modeling of the mechanism of the plant ′s response in the field environment
3、Design, synthesis and transduction of gene clusters and its evaluation

Here, we mainly focused on two characteristics of the plants：stress tolerance and resource use efficiency. These targets are more challenging compared with those that were focused on in the traditional genetic modification. Furthermore, we emphasize the importance of forming a feedback loop of the scientific knowledge, information and technology among R & D groups handling the three research issues mentioned above.

The consideration of social acceptance is also an important issue in developing the technology and promoting it in society. Therefore, solicitous assessment of the technology concerning its influence on the natural environment and human society should be performed, and the transparency of the research should also be secured.

As a consequence, a societal effect on establishing“ Sustainable Agriculture” with low resource and energy consumption is expected to be realized on the basis of the technology we propose.

## 31. Development of Translational Health Informatics Base【Executive summary in English】

This strategic program proposes the development and utilization of the informatics base (we termed as translational health informatics base (THIB)) which enables " the circulation of knowledge" in the medical science and clinical services.

By developing THIB, the fruits of life science research, personal medical information and clinical care data become interoperative. As a result of this, we can expect the following effects: the progress of epidemiological studies, improvement of clinical services in their qualities and efficiency.

It has been discussed that we should perform "Health Research" which enables us to make use of the fruits of latest life science research and to return it to the society as a more advanced treatment method, medicine or medical instrument. To this end, the Health Research Promotion Council was established in Japan under the control of the Cabinet Office in 2008. In the "Health Research Promotion Strategy" proposed by the Council, it is recommended that we establish "the circulation of knowledge" loop in the medical science and clinical services by clarifying the mechanism of life phenomenon and diseases, converting the clarified mechanism into diagnostic and treatment methods, identifying new research subjects through assessing the effectiveness of the methods, and carrying out research on the identified subjects.

Several projects have been promoted for developing information infrastructure to smoothly turn the fruits of the life science research into clinical services. These projects are aiming at creating the basis to fully utilize data base in the life science fields and improve the efficiency and quality of life science research. However, these projects did not have enough coordination with the studies performed in medical institutions and there is much room left to enhance "the circulation of knowledge" loop in the life science research and studies performed in the medical institutions. From this point of view, we propose comprehensive development of those information infrastructures as THIB which allows us to link cutting-edge knowledge in the life science, clinical data, medical data, health examination data, and epidemiological study data. When developing and utilizing THIB, we need to fund not only in informatics studies, but also infrastructure build-up, standardization activity, common tools, and sustainable operation of THIB.

Rather than trying to develop a full-scale THIB system from the very beginning, we should start from a small trial-phase project and gradually expand the institutional community. From a practical standpoint, an emphasis should be placed on the federation of the existing systems throughout the development.

## 32. Synthetic Biology for Science and Engineering【Executive summary in English】

Synthetic Biology is currently focused on as biological production technology that tries to manufacture energy and chemical industrial materials with microorganisms, etc. It is a recombinant DNA technology that is expected to make a technological contribution to the realization. However, the current recombinant DNA technology uses only one or a small number of gene functions and it is difficult to manufacture a complex of numerous proteins or a complicated chemical compound other than proteins. In order to overcome this point and use this biological production technology in biology-using industries and medical area in an advanced and widespread manner, it is required that the technologies which can fully control complex biological functions, caused by numerous biological activities.

Recent development of life science, elucidation of mechanism of biological functions created by networks of genes and proteins has greatly improved and much knowledge and information have been accumulated. Based on those findings, we are now able to obtain a technology added with a new function which was not originally possessed by the cell by designing a network combined with many genes and proteins and building it into the cell.

Based on the above, this proposal recommends to establish (1) a technology to design a biological function involved in matter production within the biological body from a network of genes and proteins by referring to metabolism function, etc., (2) a technology to actually demonstrate the function by adding the designed biological function to microorganisms, etc., (3) standardize a method to ensure the safety of handling the microorganisms, etc. which are added the new biological function, and (4) promote R&D of establishing a manufacturing method of useful substances which are difficult to manufacture with the existing methods. Through these, we need to design biological functions to produce petroleum components such as gasoline and other useful substances with complicated structures and focus on R&D to create microorganisms and cells added with these functions.

Several noteworthy achievements have begun to appear in “Synthetic Biology for Science and Engineering”, and research investment by the government in this area has been accelerated in Europe and the United States. In particular, the United States has been a step ahead in the R&D of biofuels using this technology. On the other hand, while Japan is lagging slightly behind in the production of biofuels and other useful substances by organisms, the level of research in Japan is either equaling or surpassing that of Europe and the United States at this time because of Japan's high-level technological capability nurtured in fermentation and food industries as well as achievements in important basic studies including iPS cells. Therefore, by quickly promoting R&D is important especially in the areas, such as genetic engineering, protein engineering, systems biology, synthetic biology and MEMS technology in Japan as well.

The research to design and establish biological functions is still in the early stage around the world. Because of that, the risk is high in many aspects and it is hard to push the R&D forward only by private companies. As is the case with a recombinant DNA technology, it is necessary to give due consideration to bioethics and social acceptability. It is important that the government take the initiative to promote and work to define "safe technologies" to use biological functions.

## 33. Understanding and Controlling Biological Process of Chronic Inflammation 【Executive summary in English】

This strategic provides a research and development strategy to create the basis of pre-emptive medicine which would be needed in an aging society. The strategic plan includes the research to unravel and control biological mechanisms in which acute inflammation turns to chronic one causing serious disease.
In this strategic program, we focus on inflammation that is invoked when a living body receives harmful stimulation. We recommend two research programs to be promoted. First one is a research to reveal how inflammatory reaction which rapidly resolved in usual turns to chronic inflammation causing a new disease. The second one is a research to develop controlling mechanisms to resolve chronic inflammation. The integration of above two approaches would establish the foundation of pre-emptive medicine for inflammation-related diseases that have become a big social and medical issue in future few years. The research programs cover not only the biological hierarchy from molecules to cells but also the one from tissues to organs.

It has been widely known that inflammation is reddening or swelling with fever and pain, as well as a repair mechanism invoked by the living body against infections and tissue injuries. However, recent studies suggested that unresolved inflammation may invade the living body in an uncontrollable condition and become a factor to cause various diseases such as neurological/muscular diseases, gastrointestinal diseases, psychiatric diseases, metabolic diseases, bone/cartilage diseases, cardiovascular diseases, sensory diseases, autoimmune diseases and cancer. Even that, it is still unclear how inflammation becomes chronic, triggers a disease and what kind of physiological role it plays. In Japan, the aging society is rapidly growing, and numerous inflammation-related diseases have brought serious problems. Although anti-inflammatory drugs have been available for many years, some of them induce adverse reactions as a result of the long-term use. We need to understand deeply the biological process of inflammation which is very common physiological reaction among the diseases described above. In the World, the research programs to approach inflammation have been focused from 2005, and several strategic programs have been developed. On the other hand, Japanese government does not establish a flame work to integrate individual inflammation-related approaches, such as immunology research, to clinical applications.

This research and development strategy is based on the study of understanding and controlling inflammation in the living body system to deliver foundations for pre-emptive medicine as follows.

1. A fundamental technology which progress the development of medicine, such as detection of turning point of the inflammatory reaction from acute to chronic and visualization of the causal relationship between the occurrence of an etiology and the development of a disease in molecular, cellular, tissue, and organ levels
2. A therapeutic foundation based on the inflammatory mechanism in the living body system, which resolves inflammation without generating adverse reactions

If the above fundamental technologies are progressed to develop pre-emptive medicines, one can expect the creation of vaccines, preclinical treatment/biomarkers for inflammation-related diseases. From the perspectives to control inflammation in the focus of a disease, this research strategy may also contribute to the development of regenerative medicine.

In the strategic program “Understanding and Controlling Biological Process of Chronic Inflammation”, we recommend to progress integrative studies covers not only the molecular and cellular biology but tissue and organ physiology based on immunology, stem cells, cardiovascular system, cancer, and neurological research fields. Therefore we provide following three approaches for this research strategy.

1. Biological mechanisms breaking down normal controlling process of inflammation
2. Developing process of diseases which is triggered by chronicity of inflammation.
3. Technology development to assess the suitable understanding and controlling the biological processing of chronic inflammation.

The current strategic plan aims to develop basic biological studies to clinical trials. According to the research team organization, molecular and cellular research core groups can collaborate with clinical research or technology assessment groups. Individual research team would progress the fundamental technology to develop in vivo control system of inflammation as well as clinical and pre-clinical researches including animal models. In addition to the team project, small individual projects should be progressed in the same time or in advance to enlarge the related-research community.

In result, the investment of strategic program “Understanding and Controlling Biological Process of Chronic Inflammation” may bring us various biological basis of pre-emptive medicines for inflammation-related diseases to sufficient current and future medical demands in Japan

## 34. Proposal for developing a new office to promote and coordinate clinical researches【Executive summary in English】

The life science field is positioned as one of the four priority fields that should be promoted in the Science and Technology Basic Plan and intensive investments have been made to lead the achievements in this field to innovations such as new drugs and medical devices. The efforts to promote health research have been made by promoting the fundamental research, translational research and clinical research, improving and upgrading the infrastructure for clinical research and the environment for clinical trials. This is because the health research has become an extremely important issue in Japan that faces rapid aging and a falling birthrate.

In order to lead the achievements in the life science research to promotion of health among the public, strategies eyeing from the fundamental research to clinical research on human beings and epidemiological research and their effective operation are indispensable. However, in the current situation, discontinuity of research and development due to sectionalism in the related government offices has been pointed out as a problem that particularly impedes efficient use of research expenses.

In order to break down these problems, the “Health Research Promotion Conference” was founded in the Cabinet Office to advance health-related translational research, clinical research, etc. that have been promoted individually by the related government offices in a unified and intensive manner based on one strategy. The Center for Research and Development Strategy of the Japan Science and Technology Agency (JST-CRDS) conducted the surveys on such countries as the United Kingdom and Singapore that founded the command centers for clinical research ahead of others and examined the current problems of health research in Japan and roles that this command center for clinical research should play in order to make sure that this conference will effectively function.

This proposal proposes what the health research control tower ought to be in order to establish this Health Research Promotion Conference in Japan as an effective organization. Specifically, we expect that it will play the role as the health research control tower by setting its mission as drawing up of health research strategies after focusing on the current situation and future of our social status, demographics and disease structure in order to promote the development of advanced medical technologies and by promoting the establishment of a promotion panel that has functions of a think tank and funding management, efforts for economic evaluation of drugs and medical devices, improvement of infrastructure for clinical and epidemiological research and development of human resources.

## 35. Quantitative Analysis Research for Multiple Food Functions - Advanced Food Science toward Health and Safety through the Fusion of Agriculture, Engineering and Medicine -【Executive summary in English】

The strategic proposal , “Quantitative Analysis Research for Multiple Food Functions” is research and development to quantitatively analyze and reveal food characteristics, weak, delayed and multiple/diverse functions, using individual organisms, cells and human digestive tract models. The term “food functions” here includes not only health maintenance/promotion and disease preventing effects by food composed of multiple ingredients but also a function that poses a hazard to human bodies (toxicity: ingredients originally in the food and foreign ingredients such as agricultural chemicals), which is related to food safety.

This strategic program focuses on the “food function” that poses a hazard to human bodies and proposes research and development that contributes to health maintenance and disease prevention by food, as well as realization of securing food safety. While quantitative analysis of functions has made considerable progress in “drugs” with single components, there has been almost no progress in food that is originally made up of complex and diverse ingredients. In recent years, the number of patients affected with lifestyle-related diseases such as diabetes and hypertension has been increasing. Against such a situation, the concept of “Ishoku Dougen, in other words, medicines and foods share the same origin that means consuming foods for health is spreading in order to prevent diseases. This is considered a new trend towards realization of preventive medicine from “Treatment by Drug” to “Prevention by Food.” In order to maintain healthy by food and realize prevention of diseases, it is necessary to reveal functions of the food and consume an appropriate amount of food that is suited for the constitution of an individual. However, because a variety of ingredients contained in the food respond intricately in the living body and its effects appear in a weak and delayed manner, analysis of the food functions was believed to be difficult.
Then, this proposal proposes to challenge quantitative analysis of food functions, which used to be mysteries, through the development of an assessment system for multiple food functions in the three levels of living bodies; (1) individual organisms, (2) tissues/organs, and (3) cells. Major research and development issues in each level are as follows:

(1) Functional assessment by regulatory markers and development of new safety

assessment methods

(2) Multiple kinetic analysis and functional assessment of food ingredients by establishing an artificial digestive tract model

(3) Understanding of disposition of multiple food ingredients, identification of target factors and elucidation of mechanism of action

Since food functions are complicated, the assessment results are not necessarily consistent in the three levels. Therefore, the perspective to integrate the analysis results and comprehensively judge them is important in future food research.

In order to move forward the aforementioned research and development to the level of practical application in medium- and long-term standpoints, it is essential not only to allow researchers in different fields such as agriculture that studies food functions, engineering that develops an assessment technique, and medicine that evaluates effects and impact of food on human bodies to collaborate and fuse with each other, but also to establish a cooperative system with industries that actually develop functional foods.

This proposal is an investment strategy for the fundamental research issue, taking advantage of strength of food science and engineering in Japan, and the following social and economic spin-off effects are expected: (1) realization of health maintenance and preventive medicine by food and securing of scientific safety of food, (2) expansion of food market by development of new functional food, and (3) significant progress in the field of nutritional science by advancement of science and technology of Japanese origin that assess food functions in a multiple and quantitative manner.

## 36. Interactive Brain Information Technology【Executive summary in English】

This proposal of “Interactive Brain Information Technology (IBIT)” aims to develop a technology to restore the ability of operating machine and of sensing which is weakened or lost as a result of disabilities in the body through interactive exchange of information between brain and outside world.
For this purpose, we need to establish a technology for each of the following factors and develop the integrated technology.

1) Detection of signal from the brain
2) Analysis of information from the signal
3) Control of external equipments by the analized information
4) Feedback of information to the brain
5) Understanding of plasticity of brain during the information interaction

The establishment of the above technological foundation is expected not only to support or restore human functions lost by disabilities but also to serve as the foundation of technologies to control multi-degree-of-freedom motion that cannot be realized under normal conditions or to utilize brain activities under the unconsciousness.

By carrying out the research and development in this proposal, the IBIT is expected to contribute to improvement in the quality of life of the people with disabilities as a technology to support their activities, while providing a significant breakthrough in the elucidation of brain functions. This technology closes in on the operating principle of the brain itself, including how the information is encoded in the brain and how it is used.

Since this research area forms the integrated area that includes a very wide range of areas, it should be advanced as applied research and various applications in the development of technology to the society in parallel to different development phases. Therefore, we think that the Brain Science Committee, which has been established under the Research Plan and Assessment Subcommittee and the Science Research Promotion Panel of the of Science Subcommittee of the Council for Science and Technology of the Ministry of Education, Culture, Sports, Science and Technology, is an appropriate organization to oversee this research and development as a fundamental research and should provide a long-term operation of this research and development.

## 37. Innovation in Drug Assessment Technology Based on Human Biology 【Executive summary in English】

In the current development of new drugs, there are serious problems such as a decline of the success rate and enormous research and development costs. Regarding new drugs represented by biotechnology-based drugs and molecularly-targeted drugs in recent years, the technology to assess their safety and efficacy has not been established yet, which has become one of the causes for prolongation of clinical development. Furthermore, despite that there are the wealth of fundamental technologies in Japan that can be applied to drug assessment such as a technology to create iPS cells and a measuring technology using optic engineering, many of them have not been fully utilized as the technology for drug assessment. In addition, safety and efficacy assessment data in the drug development phases from the pre-clinical to clinical studies have not been integrated and many of the technologies are not linked to acceleration of the entire drug development.

Based on the above situation, we propose to promote research and development to establish a “Drug Assessment Technology Based on Human Biology” as the integrated assessment technology to predict and prove the safety and efficacy of drugs in a highly accurate manner. The “Drug Assessment Technology Based on Human Biology” is the integrated assessment technology to predict and prove the safety and efficacy of drugs in a highly accurate manner based on recent development of life science taking advantage of deciphering the human genome. It develops an assessment system that integrates from pre-clinical to clinical phases in the drug development by standardizing human biological materials and human biological information and unifying them organically. When further amplified, it conducts research and development of the following elemental technologies.

[1] Development of cellular and organ materials mimicking human bodies and model animals
[2] Development of an objective clinical assessment method using molecular imaging, etc.
[3] Development of a technology to consolidate/integrate assessment experiment data by mathematical model, etc.

When promoting these research and development, it is desired to establish a virtual research and development platform to let the people be clearly aware of the exit of drug development and implement them under strong leadership by PO, etc. Specific targets should be laid out, for example, to establish an integrated assessment experiment system to predict toxicity of low-molecule compounds and an immunotherapy assessment system in the development of antibody drugs and to develop an assessment technology for the safety in the body in the development of nucleic-acid drugs, and the related assessment technology groups should be promoted in an integrated manner.

With this research and development, it will become possible to eliminate the difference in drug responsiveness that is attributed to species difference, which was difficult to evaluate with the conventional in vivo response assessment using model animals such as rodents. Furthermore, the establishment of a technology to consolidate the safety and efficacy assessment data will enable to build a system to accurately assess the efficacy and safety based on human materials from the clinical phase. In addition, this research and development can make a great contribution to the development of regulatory science to achieve quick review and approval of drugs in response to the current situation in which pharmaceutical companies, companies commissioned with drug assessment studies, governmental offices responsible for review and approval of drugs have been unable to share the latest technologies.

## 38. Developing a new regulatory authority for Drugs and Medical Devices 【Executive summary in English】

We see striking progress in the recent life science, but the implementation of a clinical research on human beings is indispensable to use the achievements in medical practice. However, the clinical research now remains flat in Japan and the applications of new drugs and medical technologies have been delayed, making us a developing country with advanced medicine. This is a serious problem in Japan that has already entered an aging society and requires further upgrading of medicine.

There are several reasons why the clinical research in Japan is lagging behind. A particularly important issue is a problem of the review/approval system for drugs, medical devices and biological products. The review/approval for candidate substances as new drugs is an important work that is required to fully recognize uncertainty included in the medicine itself, make scientific evaluation of the safety and efficacy, approve the drug as new medicine and ensure that the public can quickly receive the benefit. For this purpose, the standards and procedures of the review/approval have been continuously examined and improved around the world. However, compared with such global trend, the improvement of the review/approval system in Japan is clearly lagging behind other countries.

This proposal proposes the following measures to the government and related organizations in order to reform the review/approval system for drugs, medical devices and biological products.

1) Revision and improvement of legislative systems for the review/approval

To unify the management of regulations and review when carrying out a clinical research using candidate substances for new drugs, etc.

2) New establishment of Drug Agency (provisional title)

To revise the current system in which the review and approval organs for clinical research and the approval are separated, integrate the review-related sections (e.g. Evaluation and Licensing Division) of the Pharmaceutical and Food Safety Bureau of the Ministry of Health, Labour and Welfare (MHLW) and the Pharmaceuticals and Medical Devices Agency (PMDA) and improve the system as the Drug Agency (provisional title)

3) Strengthening of human resources involved in the review/approval

To promote the development and strengthening of human resources in the regulatory authorities through the thoroughness of job principles and revitalization of personnel exchanges and penetrate a new concept of regulatory science into the people in both the review and development sides.

The introduction of these measures enables safer and more effective medicines to quickly spread in the society and achieve the improvement of national health and medical care. The progress of science and technology in the life science filed, development of healthcare industry in Japan and upgrading of Japan’s international contribution can be also expected.

## 39. Integrative Celerity Research (ICR) for Medical Devices【Executive summary in English】

Medical devices surrounding us serve in many ways for diagnosis of diseases, treatment, health and improvement of QOL. For example, the introduction of a gastroscope realized early diagnosis of gastric cancer and nearly halved the mortality from gastric cancer compared with that in the 1970s. With recent introduction of positron emission tomography (PET), there are great expectations for early diagnosis of intractable diseases such as Alzheimer’s disease and cancer.

Despite of high technical capabilities in such areas as electronics, semiconductors and materials and many potential technologies that could become a core in new medical devices, the reality is that the development of medical devices is lagging behind in Japan. In the export and import of medical devices, there is an import excess of over 500 billion yen. There has bee almost no ongoing development of therapeutic devices that may be at high risk for human bodies. The attitude towards the development fearing of an accident in the worst case is a problem by itself, but the biggest cause is attributed to the fact that a system to promptly advance clinical research for the development of a medical device, to which improvements are often made while actually using it, has not been improved.

In order to break down such situation, we need measures to promptly advance the development of innovative medical devices, while solving various problems in terms of research and development, industry and regulations. For this purpose, we have applied the concept of “Integrative Celerity Research (ICR)” that forecasts goals of clinical studies and advance each research and development phase in an integrative and prompt manner to the development of medical devices and surveyed the current situation and problems in the development of medical devices. As a result, we make the following two proposals as effective measures to solve the problems arising in the development of medical devices.

1. Introduction of new application system for medical devices (Japanese-version IDE):
   To consolidate a consultation service for the development of medical devices and introduce a system that enables the review side to give advice and support to the development side from the initial stage of research and development. At the same time, to relax the regulations according to development phases and consider a

mechanism that reduces the research and development costs.

2. Establishment of a research and development platform that has a commanding role:
To establish a system that allows consistent support from a seed stage to practical use to achieve the development of innovative medical devices. For this purpose, to build an organization with a commanding role and introduce a system that allows related government offices, the Ministry of Education, Culture, Sports, Science and Technology, Ministry of Economy, Trade and Industry and Ministry of Health, Labour and Welfare, to provide continuous support from each position. In the development of high-risk devices in particular, to clarify the roles of universities, ventures and leading companies and make sure efficient development of medical devices.

By realizing the above proposals, we can expect to clarify review standards which were unclear, make the development process of medical devices by the concerted efforts of the public and private sectors smooth and dramatically promote clinical applications of advanced manufacturing technologies and life science of the Japanese origin. On the other hand, technologies and companies in different fields can also join the development of medical devices, revitalizing the medical device industry itself and enhancing the attractiveness of the industry. As a result, it will be possible to use domestic pace makers and cardiac/coronary artery catheters that now depend on imports. It is also expected that guarantee of health and medical care of the Japanese people by domestic products, which has not been currently realized, may become possible.

## 40. Chemical Genomics for Cellular Regulation Technology 【Executive summary in English】

With the progress of genome projects, the analysis of structures and functions of more than 100,000 types of proteins which are assumed from genetic sequence of human genome has been energetically underway around the world.
Against this background, there are high expectations for the so-called chemical genomics that aims to comprehensively understand the cellular functions in a genome-wide approach using low-molecular-weight compounds.
In order to regulate the cellular function, it is necessary to identify a protein that becomes a controlling target and synthesize the most appropriate compound to act on the identified protein. However, because these techniques are still immature, it is currently impossible to regulate most of the cellular functions. Therefore, we aim to achieve a regulating technology of various cellular functions by using natural compounds with the development of the following three technologies at the core.

1. Screening technology for exploring compounds with physiological activity
2. Identification technology of cellular regulation protein
3. Technology for optimizing physiologically active compound

The reasons why we dare to select natural compounds in promoting this R&D include; there are originally various kinds of natural compounds; many of them have physiological activities; and Japan overwhelms other countries in the absolute number of possessing compounds, the synthesizing technology, etc.

Furthermore, the reasons why we focus on analysis of cellular expression, not directly targeting proteins, are that Japan has advantages in technologies to visualize and measure alteration of cellular morphology; the development of unique assay systems has been widely carried out; and many important cellular systems that can be controlled by compounds have been already established in the biology field.
Specifically, since many cellular studies including iPS cells and immune cells in Japan have already seized the world initiatives, we can expect to create a novel medical technology by regulating these cellular functions.
In addition to the above reasons, the Ministry of Education, Culture, Sports, Science and Technology and other organizations are promoting to improve a compound library, while studies integrated with chemistry and biology have been fostered with the

inauguration of the Japanese Society for Chemical Biology. The recent improvement of the foundation to promote these studies has also become the basis to propose this program.

Direct achievements by promoting this research field include; understanding of development mechanism of cellular functions centering on proteins and creation of compounds that can adjust protein functions and novel technologies for screening, etc. In the following science and technology fields, many social and economic effects can be expected.

1. By unraveling the development mechanism of cellular functions that used to be perceived as functional cascade of genes from the aspects of specific proteins, we can dramatically promote life science research.
2. The findings on proteins responsible for regulating cellular functions, compounds that are proven to control those cellular functions and technologies that seize these compounds can accelerate the development of new drugs by companies.

Based on the above, the meaning to invest in this field is extremely significant.

## 41. Health Evaluation Technology based on the Elucidation of Human Microbiome【Executive summary in English】

In recent years, we have begun to realize that it is necessary for development of human diseases to consider the effects of external environment such as bacterial flora in the intestine and meals in addition to these phenomena. In fact, it has been indicated that the conditions of intestinal bacteria are deeply involved in the pathological conditions of such diseases as inflammatory enteric diseases, allergy, colorectal cancer and obesity. For example, there are differences in the types of intestinal bacteria between obese people and healthy people. It has been scientifically proven that this difference is not the result of obesity but the difference in the bacterial flora becomes the cause of obesity.

In the past, it was technically difficult to analyze the dynamic state of bacterial flora, their functions and interaction with the living body and the entire picture was unknown like a black box. However, in recent years, such analysis has finally become possible thanks to rapid progress of genomic analysis technology. Furthermore, the development of related technologies is expected in the future and the time when a comprehensive analysis becomes possible by perceiving human health and diseases from the aspect of interaction with environmental factors is coming. Therefore, this proposal demonstrates the necessity to understand interaction between bacterial flora and human body using above technologies focus on the microbiome(complex microbe genomes).

As specific research issues to realize health evaluation by biological microbiome, the following issues are indispensable.

(1) Understanding of dynamic state of bacterial flora/metabolites in the gastrointestinal tract
(2) Understanding of interaction between bacterial and gastrointestinal tract
(3) Establishment of functional assessment models (germ-free animal, artificial intestinal model, etc.)

In order to pursue health evaluation by analysis of microbiome in human gastrointestinal tract, it is not enough to carry out individual studies in parallel but it is necessary to promote collaborative research that allows each research group to share information. For this purpose, as for the method to promote R&D, it is desired to form a system in which individual research groups exist around the core groups that become common basis (genome analysis, metabolite analysis, establishment of functional evaluation model, biological resources).

The promotion of this proposal will enable us to understand the relationship between the bacterial flora and the living body, which is expected to create a new technologies for health evaluation such as devices to detect a sign before a disease develops.

By establishing a daily health management system based on this, it is simultaneously expected that we can respond to social demands to reduce medical costs and promote preventive medicine as a country that reaches a super aging society ahead of other countries. In addition, by improving a platform of common basis to which private companies can join, it is also considered to promote the collaboration between private companies and the academia and contribute to development of functional food in the companies.

## 42. Urgent Proposal on Rapid Promotion of Related Stem Cell Research with the First Generation of Human induced Pluripotent Stem (iPS) Cells in the world【Executive summary in English】

In this urgent proposal, the Center for Research and Development Strategy (CRDS) of the Japan Science and Technology Agency (JST) would propose following strategies which the Japanese Government should address in promoting stem cell research, in response to the achievement of establishment of human induced pluripotent stem cells (iPS cells).

Dr. Shinya Yamanaka, a professor at Institute for Frontier Medical Sciences at Kyoto University announced a epoch making scientific achievement to obtain iPS cells which can be generatedfrom adult human skin, and differentiated to various cells such as nerve cells, cardiomyocytes, chondrocytic cells and fat cells without using human eggs (Takahashi et al., Cell 131: 861-872, 2007).
The above research achievement appeals that stem cell research in Japan would lead this research fields in the World. At the same time, it is also expected that this methodology will drastically move forward the research and development of regenerative medicine which still has unsolved ethics issues associated with the establishment of human embryonic stem cells (ES cells) and solution of transplant reaction. However, while research groups in Europe and the United States are fiercely catching up, the investment by the Japanese Government in stem cell research is not sufficient compared with those of other major countries, and the number of related clinical research in Japan is also lagging far behind.

In order to meet the medical needs of the people worldwide who are expecting the immediate implementation of regenerative medicine which can cure diseases difficult to treat with the current medicine

Within the fiscal 2007, following issues should be implemented.

1) In order to progress research on iPS cells immediately, a powerful research team under the direction of Prof. Yamanaka should be established and reinforced. It should be also urgently supported to improve and expand laboratories for the participating researchers in the team so that they can conduct their own research efficiently.
2) Urgent research budget would be funded to accelerate the research described above.

3) It is also required to form a research management team taking responsibility for coordination with related organizations supporting the above research, public relations, intellectual property rights, etc., which makes laboratory researchers to concentrate on their own research.

JST-CRDS also proposed following strategy to be implemented within 5 years after fiscal 2008.

1) Intensive investment should be funded for the progress of iPS cell and related research fields to enhance and enlarge research basis. It is also needed to establish a research system applying the iPS cell research not only to regenerative medicine, also to drug discovery and other possible areas.
2) A core institute for stem cells and related research fields should be established, which plays a key role for networking Japanese researchers as well as global ones. It is also considered for the institute to play an important role as a research hub in Asia in these fields.
3) Concrete guidelines dealing with ethical, social and legal issues would be developed to improve the environment fro suitable promotion of stem cell and related research and development.
4) Further public understanding regarding stem cell research including iPS cells would be promoted.

Note that although the JST-CRDS has already published the strategic proposal “Stem Cell Homeostasis” in October 2007, based on the opinions of many researchers including Prof. Yamanaka, we hereby make an urgent proposal in response to research achievements by Prof. Yamanaka, which was rapidly developed from the forecast made at the time.

## 43. Stem Cell Homeostasis- Fundamental Research on Mechanism of Stem Cell Homeostasis to Acceleration of Research and Development for Regenerative Medicine-【Executive summary in English】

In this strategic program, we propose the research plan to integratively understand dynamic mechanisms by stem cells including cancer stem cells and aging processes to progress the research and development of regenerative medicines.
“Stem Cell Homeostasis” promotes fundamental researches focusing on the biological mechanisms of stem cells to maintain the cellular hierarchy in human physical environment, and then develop the technology to control stem cell functions both in-vivo and –vitro for connecting basic biological findings to clinical trials. Concerning research materials, human somatic stem cells are prior to pluripotent stem cells in the views of tumorigenesis, although their pluripotency may offer tremendous seeds in the future.

It is widely expected that regenerative medicine built on cellular functions may treat incurable diseases with present medicine . In Japan, we have focused so far on the development of in vitro cellular control technology based on the elucidation of proliferation and differentiation mechanisms of stem cells particularly for the purpose of cell transplantation as regenerative medicine. Even that a growing need for the safety and efficacy of transplant cells themselves requires the technology development which predicts adverse effects by cell graft in vitro before transplantation, or optimizes the transplanted cells that can stand and function in the tissue. The above means that the understanding of the mechanisms of the homeostasis in tissue as well as the maintaining ones leads the efficient translations from basic lab research to clinical trials using cell therapy technologies. On the other hand, it is getting recognized that several intractable diseases needs novel regenerative medicine which is different approaches from the cell therapy methodology. For example, in case that the etiology is located in the niche of the patient body less effect will be expected by the cell therapy. In stead, it is better to recover the dysfunction in given tissue by chemical stimulation which may activate tissue stem cells and induce rejuvenescence. In order to realize such type of medicines with stem cell activation, we need to understand biological mechanisms to cause the aberration of niche to develop the medical technology to activate the stem cells without side effect.
Therefore, we propose a strategy to promote fundamental research on human somatic stem cells in order to accelerate the development of regenerative medicine. Especially,

following two issues are to be progressed;

1. Researches related to the maintain a homeostasis of stem cells such like “epigenetics of stem cells” and “controlling stem cells based on functions of its niche”
2. Researches related to the mechanisms to breakdown the stem cell homeostasis including “risk assessment of tumor formation based on cancer stem cells” and “impact of internal environment on stem cell functions”

The approaches of “epigenetics of stem cells”, which contains the researches which formalizes stem cell condition as well as brings biological markers of somatic stem cells may deliver fundamental findings to other research topics. By calling for proposal of this research area, it may take 5 years to connect basic studies which develop the controlling technology of stem cells to clinical trials. On should consider that the human embryonic stem cells contain more risky factors compared to tissue stem cells. It means that our proposal mainly focuses on the studies related to “epigenetics of stem cells” and “risk assessment of tumor formation based on cancer stem cells”.

By investment of “Stem Cell Homeostasis” program, we can develop technical seeds of future medicine to treat various disease and then accelerate the research and development of regenerative medicines. As a result, stem cell research in Japan would be progressed as integrative research areas in the views of human tissue formulation process and understanding the mechanisms of pathogenesis.

## 44. Promotion of Integrative Celerity Research (ICR) - Innovation in Health and Medicine -【Executive summary in English】

Currently, basic life science research in Japan is rapidly developing. The accumulation of new findings is making an incredible impact on clinical medicine. However, the medical application of these findings requires clinical research in humans, posing various problems. In Japan, the field of clinical research has many problems, thus the introduction of advanced medical technologies is delayed and falls behind other countries. This is a serious disadvantage for our rapidly-aging society, preventing Japanese people from receiving the benefit of the latest medical technologies. We have no other choice but to import many of these technologies, leading to a further rise in medical costs. In order to break this deadlock, we propose the promotion of Integrative Celerity Research (ICR).
Unlike the existing translational research, the intention of ICR is to accelerate the clinical and industrial application of research findings by setting a clear final target, obtaining a broad picture of the research, and integrating the phases of individually conducted clinical research. Through the collaboration of industry, academia, administration, and largely the government, immediate action should be taken to reform clinical research, improve the research infrastructure and reform the review and approval agency.

We therefore propose two basic policies and several measures that the government should pursue.

(1) Establishment of a basic law on clinical research
The government should establish a law to define and promote basic policies on clinical research in Japan.

(2) Improvement of clinical research facilities (especially the establishment and building of clinical research complexes)
The government should establish globally competitive clinical research complexes in Japan.

(3) Action plan for ICR promotion
- ●Securing clinical research funds
- ●System reform
- ●Development of human resources

Significant achievements like the followings can be expected from the promotion of ICR.

(1) Provision of advanced, superior medical service to Japanese people

(2) Development of a new medical industry

(3) International contribution in the medical area

## 45. Integrative Research on Innovative Exploitation and Conservation of Ecosystems【Executive summary in English】

The ecosystem and organisms that compose it have significant social values as genetic resources, resources for foods, drugs and industrial materials, environmental control mechanism, and so on. However, the reality is that the values are not sufficiently recognized and used, and there is a risk that their potentials may be lost because of the rapid deterioration as a result of the so-called act of development.

One of the causes is that the concepts of the people who study ecosystem for conservation and the people who promote the use of ecosystem crash and the cooperation between the two do not move forward, because many of the studies on ecosystems aim at conservation itself, while promoters of the use of ecosystems see the conservation of ecosystems not as the foundation of use but as "barriers" of development. Originally, knowledge, science and technology required for conservation and use of ecosystems are common in many aspects. Therefore, it is effective to carry out research and development by linking both.

This proposal perceives that advanced use of ecosystems and its expansion are indispensable for social development in the future and proposes to efficiently promote coordination of the research and development of the two to ensure the use of ecosystems as well as conservation, regeneration and reinforcement of the ecosystems that become the foundation for the use of ecosystems based on scientific knowledge and economic principles. We propose the following four areas in which the research and development should be urgently promoted.

1. Research and development on food, drug and industrial materials using the ecosystem and organisms composing it and the production technology
   Search for new available organisms and ecosystems, their usage technologies, low-environmental-load/high-efficient production technology of useful substances using the organisms/ecosystems

2. Elucidation of factors for deterioration of ecosystem services responsible for environmental control and adjustment functions, assessment of the effects and research and development of technologies for conservation, regeneration and reinforcement of the ecosystems

High-precision assessment and prediction technology for the effects of environmental pollution and climate change on the ecosystems and ecosystem services (benefits of ecosystems for humans), high-precision assessment and prediction technology for the effects of changes in the ecosystem and biodiversity on climate/meteorological phenomena and hydrologic cycle, technologies for conservation, regeneration and reinforcement of the ecosystems

3. Investigation/assessment of values of ecosystem services and research and development on adaptive integrated management technology
   Assessment technology of quantitative values of medium- and long-term ecosystem services, research and development on management and operation technologies that enable maximum use of potential capacity of supply of ecosystem services

4. Research and development on ecoomics – understanding of mechanism of ecosystem functions
   Exhaustive analysis of interaction of various organisms that compose the ecosystems and interaction between organisms and physical environment, and understanding of ecosystem functions that support the ecosystem itself and mechanism to maintain ecosystem services brought by those functions

## 46. Creation of Agrofactory - Production of Biomedicine from Animals and Plants –【Executive summary in English】

This strategic program "Creation of Agrofactory" aims to establish a system that can produce useful proteins for humans efficiently and at low cost in an easy-to-use form by transferring foreign genes regiospecifically into the animal and plant genomes.

Currently, biotechnology-based drugs are manufactured by tank fermentation of animal cells that can cause sugar chain modification close to humans. However, because there are big issues with this method such as limited productivity of cultured cells and expensive facilities such as a culture tank, building of a next-generation production system that can exceed the animal cell culture is expected. Therefore, we propose R&D to create animal and plant individuals transferred with human genes that can efficiently produce biotechnology-based drugs and present specific issues below:

1. Technology to transfer foreign genes into animal and plant genomes
   When a molecular weight is a huge protein, the development of a technology to stably transfer the relevant gene to a genome and a technology to transfer it into a specific region of animal and plant genomes is necessary. Therefore, we need to promote the development of a method to transfer a vector inserted with the foreign gene along with the gene transfer vector into the cell without causing any damage.
2. Modification technology of foreign proteins in plant
   Even if we can produce the intended protein in a plant body, if the protein does not function as an activated form that has an effect on humans, there will be no value as a drug. A key to this activated form is post-translational modification in the cell. In order to produce a protein close to a human type in the plant, we aim to establish a regulation technology of this sugar chain modification.
3. Regulation technology of protein transportation toward target tissue (organ) in plant
   In order to increase yield of transferred proteins, a lot of protein transportation technologies are necessity. In this proposal, we establish a technology to regulate functional differentiation of vacuole and related single membrane organelles, a technology to control transportation of proteins in and out of the cells and a technology to delete deposit proteins.
4. Creation of genetically-modified individual by genesis and regeneration technologies
   When enucleated eggs are injected into the cells to which foreign genes are stably inserted, initialization of a somatic nucleus (re-programming) occurs. We aim to

develop a technology that improves the efficiency of re-programming that uses a feature in which a small percentage of the somatic nucleus-transferred eggs are generated as an individual body in the host uterus and also examine to develop an in vitro culture technology of eggs used for research.

The promotion of this program enables to establish a low-cost target protein production system. This promotes not only innovation of a manufacturing process for pharmaceutical companies but also advancement of translational research and high-mix low-volume production of orphan drugs. The advanced gene modification technology also makes it possible to create an experimental animal transferred with a gene cluster such as human immune system and it is expected to create a therapeutic model for diseases that can be replaced by conventional experimental animal

## 47. Promotion of Innovation through Integration of Medicine and Engineering - A Grand Design for Integrated Medical and Engineering Research -【Executive summary in English】

Clinical medicine in Japan has a long tradition and the internationally high standard of medical care has been maintained. On the other hand, a tremendous amount of research funds have been injected to understanding of life through the research on life science and the wealth of knowledge has been accumulated as research achievements, resulting in progress of the integrative understanding. However, because the mechanism to allow clinical medicine to incorporate the achievements of fundamental research is weak, the progress of life science research has not been effectively linked to clinical research and actual diagnosis and treatment. Because of that, despite of their high potentials, innovation of medical technologies has not been fully developed. On the other hand,, potentials for technical accumulation in engineering which has supported the manufacturing industry in Japan and for solution of realistic issues are very high on a worldwide scale.

This strategic initiative proposes to connect and integrate the scientific knowledge in clinical medicine and life science by means of engineering methodologies, promote synergetic development of each discipline and meet social needs in clinical practice.

The state-of-the-art technologies to be developed by integration of medicine and engineering will enable micro-level diagnosis and treatment from cellular to molecular levels and evidence-based medicine based on engineering quantitative and reproducible capabilities. By this, accuracy and efficacy of diagnosis and treatment, as well as safety will dramatically improve compared with conventional technologies. That will also enable low-invasive and non-invasive diagnosis and treatment, enormously alleviating the accompanying pain. Such technologies are also expected to enable super early discovery of diseases and make a great contribution to preventive medicine. As a result, many people can benefit healthy and long-life living.

Although the research and development investments in this field will not be small, people can spend more comfortable and high-quality life than at present, which will lead to improvement of social values. The probability of technological innovation is also high in this field and we may be able to reverse the current situation in which there are no Japanese companies that can produce the world-class technologies other than endoscopes and some medical devices. It is also highly possible that a world-level new medical industry that takes advantage of the strengths of Japan will emerge.

In formulating specific research and development agenda, this proposal is designed not only to produce noteworthy achievements that can create social and economic values in the research and development of clinical medical technologies but also to induce significant innovation in life science and engineering through the integrative research.

## 48. Strategic Proposal on Clinical Research - Towards Fundamental Changes of Clinical Research Systems in Japan -【Executive summary in English】

Japan has invested a substantial amount of money in basic life sciences research and accumulated a wealth of knowledge. However, because the system to implement clinical research is not strong enough and there are problems with the review and approval agency, it has been difficult to lead the results of fundamental research quickly to practical use. These problems for clinical research have been pointed out before, awareness of the problems has been shared among the concerned people and each related government office has been promoting various measures for improvement. However, Japan is still lagging behind Europe and the United States in terms of swiftness and efficiency of putting the results of fundamental research into practical use. While to make drastic reform of the systems to approve clinical research and review/approve it and establish a system that quickly enables the research and development of new drugs and medical devices are pressing policy issues, there is a limit only with the efforts of the related government offices alone and it is time for us to make national commitment to addressing these issues. Although there are many policy issues, the following two are most important and require urgent response. We propose that these issues should be set into action as quickly as possible.

1. Establishment of a Basic Law on Clinical Research (provisional title)
   To establish the "Basic Law on Clinical Research (provisional title)" that includes the following contents, formulate "basic plan" based on this and strongly promote government-led clinical research.
   1) Basic policies on clinical research promotion
   2) Establishment of headquarters for clinical research promotion
   3) Roles of the government, the review and approval agency, colleges, physicians, and industries
   4) Measures to promote clinical research
   5) Improvement of the system of the review/approval agency
   6) Promotion of public understanding
   7) To state that the government should formulate a basic plan for clinical research

2. Establishment of a Clinical Research and Development Complex and building of a network of clinical research facilities

It is necessary to establish a well-organized research center to promote clinical research, namely “Clinical Research and Development Complex”. The “Complex” will consist of the following three sections: Clinical Research Promotion and Support Center; a hospital where clinical research is conducted, and an Advanced Medical Research Development Center. In the “Complex,” clinical studies targeting humans shall be first implemented accurately and efficiently. To build a “Clinical Research Network” that links clinical research implementation sites across the nation such as universities and national hospitals with a high-speed information system, centering on the “Complex,” form the cooperation structure of clinical research implementation sites in Japan and strongly carry out the nation-wide clinical research. To inject human resources and funds into the “Complex” and position it as the core base of clinical research in Japan.

Once the above systems are built, the following social effects can be expected: (1) the public can receive the latest and high-quality medical care, which realizes a healthy and long-life society, (2) the research and development efficiency for new drugs and medical devices will be improved, promoting and revitalizing international competitiveness of medical industry in Japan, and (3) all of which lead to reduce the economic burdens of the public.

## 49. Building of Design-in Food Production Systems - Realization of World's Safest, Delicious and Healthy Firm and Fishery Products - 【Executive summary in English】

A "Design-in Food Production System" is a system for value-added food production from farm that consumers will want.

The agriculture, forestry and fisheries industries in Japan face four crises. They are: [1] "Food Crisis" represented by erosion of consumer trust, [2] "Market Crisis" represented by unstable food supply, [3] "Environmental Crisis" represented by weakening of national land conservation function, and [4] "Regional Crisis" represented by loss of vitality in the regional society and economy.

Thought it's difficult to solve these four crises at the same time, we propose to establish the "design-in food production system" as the breakthrough for the solution.

For the establishment of the system, it is necessary to actively use science and technology achievements in the agriculture, forestry and fisheries industry. First, it is required to scientifically reveal the nature of safety, deliciousness and functionality of the food that the consumers will want.

Based on the results, we need to produce food with the quality and added values demanded by consumers from farm. We also need to establish a production system that supports the "design-in" method by using science and technology achievements. In addition, we must create a system that contributes to production of safety, delicious and healthy foods and conservation of natural environment of production site through communications between workes in food processing and distribution and consumers.

For these purposes, it is important that researchers in different fields and the agriculture, forestry and fisheries industry as well as other industries involved in food processing and distribution should cooperate and unite to promote research and development. Specific details are listed below.

(1) Scientific endorsement for food safety
(2) Scientific elucidation of food deliciousness
(3) Scientific relationship between food and health
(4) Establishment of a production system that support the design-in method

The establishment of the “Design-in Food Production System” allows to realize the production and supply of agricultural, livestock and fishery products as well as foods that meet both quality and quantity consumers, and it is expected to “Secure Consumer Trust in Food,” “Maintain High International Competitiveness and Secure Labor Force,” “Promote Cyclical Use of Natural Resources and Environment” and “Vitalize Regional Society and Economy.” The creation of this “Positive Growth Cycle in the Agriculture, Forestry and Fisheries Industry of Japan” can make the agriculture, forestry and fisheries industry an attractive, new industry that can contribute to improvement in quality of life of consumers and establishment of a recycle-based society and become the driving force to ensure “People” who support further development of the industry.

## 50. Cognitive Genomics - Understanding of Individual Characters of Brain Structure and Function -【Executive summary in English】

The growing trouble of interpersonal contacts such as “Social Withdrawal” and “Loss of Self-Control” and psychiatric diseases such as dementia, autism, schizophrenia and depression are social problems that will come to the surface more and more in the future. All of these failures appear as a result of activities in the human brains. In order to elucidate the reason of the failures and solve them, it is important to clarify the mechanism in which how differences in brain structure and function of each person occur.

This strategic program “Cognitive Genomics” aims to elucidate individuality of brain structure and function by integration of human genome research, brain imaging, and model animal analysis.

Specifically, major research issues combined with experimental systems using model animals, etc. are listed below.

1, Identification of biomarkers related to behavioral individuality by genomics and brain imaging
2. Generation of useful model organisms to analyze biological function of the biomarkers
3. Validation of the biomarkers and related makers found through model organism analysis for human behavioral individuality

Since the achievements including biomarkers to be obtained from these researches, which are involved in cognition, and various analytical technologies contribute to solving problems of “Mind” whose social importance will increase more in the future and “Psychiatric Diseases,” it is desired to address the issues early.

## 51. Fundamental Study for Treatment of Important Disorders using Integrative Control Function of Immune Systems【Executive summary in English】

Abnormal or excessive immune responses are deeply involved in the causes and incidence of immune diseases. Although the control of such immune responses is the global challenge, the clinical application is not easy.

This proposal aims to establish a novel and highly versatile foundation for medical care based on the following research achievements that have been promoted mainly by researchers in Japan and rapidly growing in recent years:

[1] Elucidation of a mechanism of immunological tolerance by regulatory T cells that comprehensively inhibit and control the immune system,
[2] Integrated understanding of natural immunity and acquired immunity and the utilization based on rapid progress in the recognition of infecting parasites by natural immune system and the study on defense against infection
[3] Elucidation of molecular mechanism of immunological phenomena and comprehensive understanding and utilization of building of higher-order immune tissues and formation of immunological organs both of which are indispensable for the application

Immunological control is the result of general reaction of an individual organism. The quality and quantity (degree) are regulated by the total of cellular proliferation, differentiation and maturation of cells responsible for various kinds of immunity which are gathered in the "place of immune reaction" (hereinafter referred to as "place"). Therefore, an effective clinical application is impossible unless there is the understanding of place along with the elucidation of elementary steps on a molecular and cellular level. This strategic program aims to understand these issues comprehensively and overcome the following issues that are deeply linked with each other.

(1) Development of a stable therapeutic method by artificially controlling immune reaction in the development and maintenance of pathological conditions of intractable autoimmune diseases (rheumatoid arthritis, autoimmune diabetes, etc.) and allergic diseases such as hay fever, atopic dermatitis and asthma,

establishment of preventive immunological control method and reduction of incidence of such diseases.

(2) Overcoming the difficulty of cancer immunity induction and cancellation of decline in immune reaction in tumor-bearing condition. Elucidation of various barriers that inevitably come with introduction of advanced medical technologies for cancer treatment, etc. (radiation injury, drug adverse reaction, etc.) and development of a method to overcome them.

(3) Development and establishment of a new immunological control technology that overcomes rejection associated with organ transplant and organ regenerative medicine in a self-regulating manner.

(4) Establishment of a strategy to develop new-generation vaccines (edible vaccines, inhaled vaccines) based on integrated understanding of natural immunity and acquired immunity by targeting mucosal tissues that are responsible for the primary control against emerging/re-emerging infections including respiratory and alimentary infections such as influenza and diarrhea, as well as bioterrorism that abuse the principle.

Although the research on the above issues is expected to be promoted and expanded mainly at universities, if it is designed by three players, that is, research institutes including RIKEN which promotes intensive research for each specialized theme, hospitals and universities, with a network of supplementing each one’s features and fostering successors, we can expect Japan’s leading role in the development of advanced medical care.

## 52. Systems Biology - Mechanism of Biological Systems -【Executive summary in English】

Systems biology is a study to perceive a network composed of genes, proteins, metabolites, cells, etc. as a biological system, uncover how biological functions of the network are controlled and autonomously operate against environmental changes and understand dynamic life phenomena in an integrated approach.

While the complexity of life exists because numerous genes and proteins demonstrate their functions by acting with each other, it is becoming possible to come closer to unravel the complexity by promoting systems biology.
This strategic program aims to unravel complex working mechanism of biological systems through systems biology and realize healthy and comfortable living as well as sustainable economic development by utilizing tools, technologies and software which are created in the process of verifying the mechanism in such areas as health, medicine and bioengineering.

Japan had a head start on Systems biology as approach. Although it can be said that it is still in the early stage, study on systems biology has become rapidly vigorous recently in Europe and the United States. In Japan, several internationally-acclaimed individual studies have been ongoing and the technological superiority is high in such areas as computational science and database. Therefore, we make the following proposals as specific research issues.

[1] Creation of a model to unravel working mechanism of biological systems
[2] Development of tools, technologies and software for dynamic analysis of biological systems
[3] Development of technologies for prevention, diagnosis and treatment of diseases, development of drugs and vaccines, research and development of biological production and functional food

The important things for promotion of systems biology, it require not only conventional life science research methods but also knowledge such as theoretical biology, computational science, mathematics and physics and also new tools and technologies such as quantitative measuring, imaging, microfabrication, and simulation.. In particular, system control and its theory, quantitative measuring and control and simulation should be required for the life science innovation in Japan.

## 53. Ecogenomics and Ecoproteomics for High-degree Application of Ecosystem Function【Executive summary in English】

The “Ecogenomics and Ecoproteomics” proposed by this proposal aim to extract genomes and proteins of biological group not from individual organisms but from soil and aquatic environment and unravel functions of the genes in the ecosystem.

The ecosystem is basically a flow of substances and the corresponding energy through “eat-or-be-eaten” relationships between the organisms. The organisms living in the ecosystem also produce a variety of substances such as proteins and use them for maintenance, defense, procreation, etc. of the living bodies. By detecting proteins and genes comprehensively and investigating their functions and structures in detail in order to efficiently unravel the production and cycle of organisms, we can use the results for increased production of crop plants and development of useful substances including drugs such as antibiotics. By unraveling the interaction between organisms and environment or between individual organisms, we can also understand functions and structures of the ecosystems including assimilation of carbon dioxide, water retention and environmental cleanup, enabling us to conserve them and use them in a sustainable and advanced manner.

For this purpose, we propose the following specific issues:

(1) Ecogenomics and ecoproteomics focusing on analysis of substances produced by organisms and a technology to produce useful substances

(2) Ecogenomics and ecoproteomics focusing on elucidation of functions and structures of the ecosystems

(3) Ecogenomics and ecoproteomics focusing on a technology to search for species of organisms

The above research and development issues significantly deepen the understanding of functions and structures of the ecosystem, which becomes an important industrial foundation in the future. The research and development issues proposed in this proposal can also contribute to enriching a library of genetic resources and keeping the Japanese industrial competitiveness for a long term, because there are many technological seeds in these issues such as development of equipment, and so on. In addition, they are also expected to promote integration between biology/environmental science in macro approach and biology in biotechnological approach and the coordination with researchers of mathematical science and information processing will be essential. This strategic proposal also aims to induce innovation through the development of integrated academic fields extracted from these needs.

## 54. Nanoscale Thermal Management for Device Innovation – Phonon Engineering –【Executive summary in English】

The understanding and control of thermal properties in nano space and very short time scale are becoming more and more indispensable for solution of the information explosion, as well as for highly efficient utilization of energy which are required in the future society, since the innovation of devices for information processing and storage, and for thermoelectric conversion are confronting a limit due to heat problems. The present proposal relates to the establishment of a new academic field concerning the nanoscale heat management based on the concepts of phonons and the promotion of R&D activities toward the innovation of devices in terms of phonon engineering.

It is well recognized that the convenience of our lives has been greatly improved by higher performance of devices in the recent information-intensive/network society. On the other hand, however, the amount of newly generated information has been increasing dramatically, and is forecasted to reach 40 zettabytes (1021) by 2020, about ten times the present amount. To deal with the information explosion, continued technical innovation in information processing and the achievement of substantially higher performance and power saving by data storage devices are strongly required for the future. However, in a semiconductor integrated circuits, the problem of heat generation and dissipation by miniaturized devices on a nanoscale constitutes the limiting factor against advanced performances. In addition, the hard disk storage devices are also confronting a capacity expansion limit due to the thermal fluctuation of magnetized area in nanoscale. To resolve such problems, the development of nanoscale heat control methods and devices featuring a new operating principle which proactively utilizes the heat generation on a nanoscale is strongly expected. Under such circumstances, understanding the nanoscale behaviors of heat transport, and controlling and using the characteristics thereof will become strongly important.

In the nanoscale, the heat transport in a material should be treated in terms of the transport of phonons, which are quanta of lattice vibrations. The concept of phonons is rather old one since it is discovered around the beginning of the 20th century. Nevertheless, the understanding and the control technologies of heat based on phonons were much delayed compared to electronic properties and optical properties, since deep understanding and control have rarely been necessary for device development to date. Now that the miniaturization of electronic devices, optical devices, and magnetic devices proceeds to the nanoscale level, less than the mean free path of phonons, the correct understanding of device operations and designing is impossible unless electrons, photons, spins, and phonons are handled in a unified manner. Therefore, in the present proposal, the purpose is set out to ensure the establishment of a new academic field and the innovation of materials and devices by deepening the understanding of heat in the nanoscale region from the perspective of nanoscience, thereby establishing heat control and utilization technologies. Here, the new academic discipline to manipulate the transport of phonons and control the transport of heat by handling the transport of heat with the concept of phonons and using artificial structures will be referred to as phonon engineering. Proposals will be made regarding the subjects of R&D and the promotion system thereof that will be required for this purpose.

The research issues include heat measurement, theory/simulation of phonon transport, and phonon transport control by manufacturing materials and structures, and it is necessary to establish a new academic field that should be referred to as the thermal nano-science and the thermal nano-engineering. Furthermore, it is also important to create revolutionary technologies for materials and devices by understanding the quantum systems, including phonons, electrons, photons, and spins, in a unified manner and controlling the nanoscale physical phenomena where the quantum systems are intricately intertwined. More specifically, it is necessary to execute the following research and development activities.

Correct understanding of the phenomena regarding thermal properties at the nano-level requires a development of new methods and equipment capable of measuring the actual temperatures and heat conduction on a nanoscale with a high level of accuracy. It is necessary to improve the measurement accuracy in the conventional optical thermo-reflectance method that have been used for evaluation of heat conduction for a long time; expand the measurable range in time, space, structure, etc.; and develop new evaluation methods and equipment, including the scanning thermal probe microscope that is capable of measuring the nanoscale local structure with a high level of accuracy. In addition, it is also necessary to develop an evaluation method that will enable to obtain not only the steady state but also the transient state information of heat.

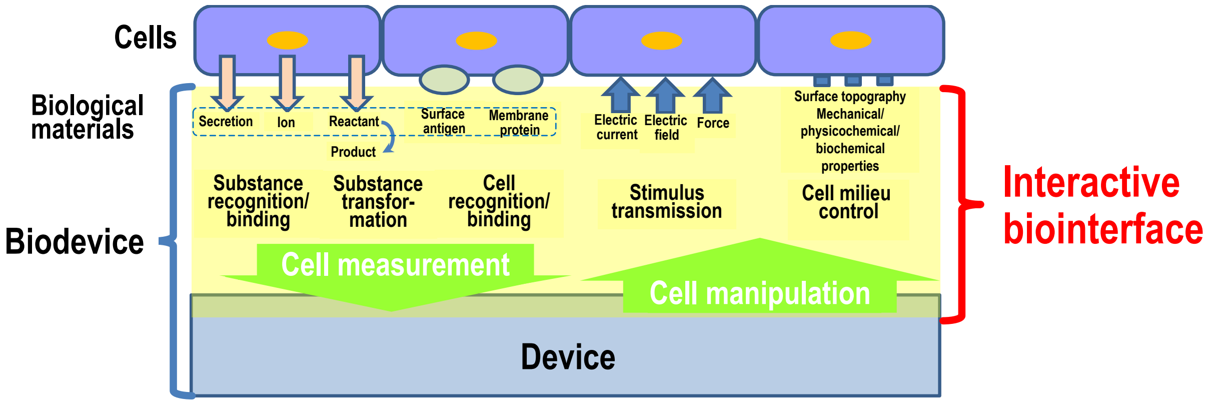
Establishment of the theory of heat conduction on the nanoscale taking into account the aspects of surfaces, interfaces, impurities, structural defects, etc., as well as development of the simulation algorithms are required. Here, it is also necessary to handle the heat transport on a nanoscale not only in terms of solely the size, but also taking account the scattering of phonons on the structure/material of low-dimensional systems, ie., ultra-thin films or ultra-fine wires, surfaces of materials, and interfaces of dissimilar materials. For the simulation, it is necessary to establish the art of computation that can easily calculate the parameters of basic thermal properties of materials in a theoretical manner by expanding the scale, increasing the accuracy, and improving the operability of the programs that calculate the behaviors at the atomic and molecular levels from the fundamental principles of physics. Furthermore, it is also necessary to develop the simulation algorithms for phonon transport in the actual materials and device structures by skillfully executing theoretical computation methods using the parameters of thermal properties, in particular, the multi-scale simulation that makes simulation algorithms at different scales to work interactively. It is important to investigate the control methods based on the understanding on the nanoscale heat transport, according to the phonon transport concept, thereby systematizing the methods as an integrated technology. More specifically, the materials and the device structures should be manufactured by introducing the interfaces, impurities, structural defects, dissimilar materials, microstructures, periodic structures, etc., thinner films and lower dimensions, thereby understanding the effects thereof on heat transport in an experimental manner. In addition, the comprehensive research and development activities to confirm the effects theoretically and through simulations and incorporate the knowledge obtained in the processes in the material design and device design are required. Furthermore, it is also important to work on new control methods through the formulation of artificial structures, such as a phononic crystal structure that controls the diffusion of phonons by utilizing the properties of wave motions of phonons. For such control approaches of heat transport at nanoscale, the knowledge on the manufacturing technologies of artificial structures to control electrons and photons which are established in the electronic devices and optical devices for a long period of time are expected to be utilized proactively. Research studies where the scenes to apply the heat control technologies through the nanoscale phonon transport and the operations thereof to actual application fields are assumed are also important. Here, it is necessary to give simultaneous consideration also to the control of phonons and other quanta including photons, electrons, and spins. Along with the development of the simulation method that is capable of handling such quantum systems in an integrated manner, it is important to proceed with modelling for easy handling and proceed with R&D work on the material/device design methods where the models are utilized. Through such arrangements, it is expected that the characteristics of the semiconductor integrated circuits, power semiconductors, next-generation hard disk drives, thermoelectric conversion elements, etc., where the nanoscale heat transport is a bottleneck in terms of performance and function, can be improved. Furthermore, the technologies can be developed for use with the new devices, such as memory devices and sensors where nanoscale heat control is utilized The most important thing concerning the promotion method of R&D work is that researchers and engineers involved on nanoscale heat conduction should make efforts while sharing the goals of R&D work, extending the boundaries of academic fields and application fields. The nanoscale heat control that has been overlooked so far is a tough proposition, and achievement will be unlikely unless the goals are shared between scientists, engineers, and researchers among industry, academia, and government. In addition, for the promotion of R&D work, the formation and development of community will be very important. The reason is that the nanoscale heat control cannot be handled with the expert knowledge and the technical territory region of a single field, and the opportunities where researchers and engineers get together, across the boundaries between different academic fields or between application fields, to make discussions and the network environment enabling close information exchange at any time will be required. At the same time, participants from different fields will have to assume the role of cooperating and executing joint research, develop apparatuses, and cultivate human resources. In this regard, it is necessary that, for example, the researchers of materials and devices, and the researchers involved in thermal property measurement and heat conduction theory/simulation will execute research work under one roof. Furthermore, for the present research and development, it is recommended to establish and operate a knowledge base on heat properties that can be shared widely by researchers involved in R&D work. Regarding the thermal properties of materials and devices in nanoscale, there has been no systematically organized knowledge base to date, and such heat properties have not been established as an academic field, which constitutes the barrier for researchers to enter the area anew. It is important to build a detailed database concerning the nanoscale heat properties and establish and organize an environment for usage and tools to which related researchers can access freely for use. From a global perspective, although the United States is in the most advanced position concerning individual research and conceptual representation, intensive approaches that include programming work according to the policy have not been implemented yet in any country. Therefore, now is the right time to design and implement a policy

## 55. Creation of Interactive Biointerface – A fundamental technology for biodevices to enable dynamic analysis and control of cells【Executive summary in English】

The expectations for the practical application of stem cells to regenerative medicine and drug discovery have prompted rapid progress in cell research. To facilitate the smooth development of practical applications based on the outcomes of cell research, it is also essential to promote the development of technologies that enable cell measurement and manipulation.

The biodevices that were developed by utilizing technologies including semiconductor electronics, MEMS, and microfluidics are becoming capable of measuring and manipulating cells at unprecedentedly low levels of several tens of nanometers. However, there is a wide range of variations in the types of cells, and each cell varies from moment to moment on the changes in the immediate environment. Therefore, sophisticated design and construction of so-called "biointerface," which is the interface between the artificial devices and the biological cells, hold the key to achieve accurate measurement and proper manipulation of such complex subjects as cells.

We hereby propose implementation of research and development aimed at the creation of an "interactive biointerface," which is defined as the "structure composed of the surface of the device and the material layer that is formed on the surface of the device that functions to detect cells and biological materials on the side of the device, and transmit the signals from the device to the cells. This research and development covers the fundamental technology that determines the success or failure of the global trend of applying electronics technology to bioscience and biotechnology. In order for Japan to become a world leader in this field, it is essential to strategically promote research and development of the field as a nation.




The interactive biointerface should possess the following functions.

(1) The function to recognize and bind to substances that are secreted or released by cells and to convert them to substances that the devices can detect using specific reactions.【substance recognition/binding/transformation function】
(2) The function to recognize and bind to surface antigens and membrane proteins of the cells.【cell recognition/binding function】
(3) The function to transmit stimuli from the device to the cells.【stimulus transmission function】
(4) The function to control the milieu that affects the activity, differentiation, and proliferation of the cells.【cell milieu control function】

To realize these functions, research and development concerning a broad range of subjects spanning from the development of the molecules that constitute the interactive biointerface to the analysis of the interaction of the biodevice-mounted interactive biointerface with the cells is required. Therefore, research and development should be implemented by a team of scientists from various areas of specialization.

If the interactive biointerface is successfully created, real-time and high throughput measurement of cells can be applied for such purposes as quality control of the culture and processing of the cells. In addition, cell imaging that differs from traditional cell observation techniques using the optical microscope becomes available.

Since the Japanese electronics industry has a high potential to successfully develop and implement biodevices, the creation of new markets for biodevices can also be expected.

## 56. Materials Informatics – Materials Design by Digital Data Driven Method 【Executive summary in English】

The Center for Research and Development Strategy (CRDS) of the Japan Science and Technology Agency (JST) considers the establishment of "design"*1 methods for materials with target properties and functions to be important for the future of materials research. In this proposal, in order to support this activity, our study results concerning the utilization of informatics for materials research are summarized from a strategic standpoint.

As one of the future courses of materials research, the "design" of materials with functions that contribute to the solutions of problems is an essential and important concept. This involves the development of methods to rationally search for materials which possess the specified properties desired by a society or industry (inverse problem), which is unlike the traditional research procedure, in which the properties of a material are discovered from a given elemental composition and structure (direct problem). For example, if candidate materials with target properties and functions for lithium-ion batteries, thermoelectric conversional, or superconductivity can be rationally discovered, such a method will contribute greatly to the business solution in energy and resource issue and others.

In our proposal, as a new methodology necessary for the "design" of materials, materials informatics is defined as a "scientific and technical method of solving problems in materials science using computer science (data science*2 and computational science) in combination with diverse and massive collections of data regarding the physical and chemical properties of materials," and the importance of this new study area is proposed. Its most major characteristic is to qualitatively or quantitatively develop the theoretical understanding of problems that cannot be solved without the aid of computers. This allows us to deal with a massive amount of data related to materials research in a comprehensive, scientific, and systematic manner, with the aim of both promoting the discovery of hidden rules, new theories and principle, and shortening the time between theoretical discoveries and the development of practical materials.

The development of advanced materials is essential to activate many industries, such as energy, health-care, materials, and chemical industries. For more than a decade, the

Japanese government has invested substantially in research and development for the discovery and design of advanced materials. Nevertheless, a lengthy period of between 10 and 30 years is still generally required before an advanced material that is newly discovered by a research laboratory is put to practical use and entered into the marketplace. Without accelerating and shortening this process, it will be difficult to maintain the scientific and technological capabilities and industrial competitiveness of Japan in the recent situation where many industries are globalized and science and technology are no longer monopolized by certain advanced countries.

Using the traditional (existing) methods of experimental science, many types of substances have been synthesized based on experience and intuition, and their properties have been evaluated. In such methods, a plurality of experimental data regarding the structure and properties of a material is organized on the basis of various factors, and based on this activity, the functional properties of the material are estimated and theoretical models are constructed. This method has thus far made great contributions to materials research.

Due to recent advancements in computer science as well as computational power, and also reductions in computer costs, many laboratories have been able to perform analyses of experimental results to understand at an electronic theory level on a daily basis. Even before an experiment is undertaken, they are able to often estimate electronic orbits and electronic structure in order to predict whether a target function or property will be obtained.

Based on the above background, a collaborative effort between the three core study areas of materials synthesis/processing, measurement/analysis, and theory/simulation, has recently been initiated in order to advance the effectiveness in materials research, which should be resulted in substantial progress in communication between experimental and computational scientists. Fundamentally, however, such collaborative efforts, by themselves do not make it possible to “design” a material which possesses a target property or function. Accordingly, it remains difficult to progress beyond the standard method of obtaining a target function by a trial and error approach based on experience and intuition.

As a new means of promoting “design” beyond the existing approach, we propose the introduction of informatics, with the construction of a data-driven model to inductively gain knowledge (rules) from massive, complicated sets of data. This will produce a synergetic effect in parallel with use of a deductive approach (principle-driven) based on theories or models, which may lead to great advancements in future materials research.

The total number of substances that have heretofore been synthesized, and the amount of information on the properties of these synthesized substances are enormous.*3 In fact, it becomes increasingly difficult to obtain prospects for the development of novel materials using only traditional guiding attributes, such as crystal structure and molecular formula. Furthermore, recent advances in measurement and simulation techniques have resulted in the short-time generation of an enormous volume of data. Because the volume of this data will doubtless continue to increase steadily in the future, in order to extract meaningful information from such massive data, a higher-order concept (new axis) is required to obtain a holistic view of this massive materials data and to organize such data in a comprehensive manner.

In recent years, in the area of data (mathematical or information) science, rapid progress has been made in multivariate, high-dimensional data analysis, in terms of methods to extract the information structure inherent in massive or complicated data. Methods for the scientific analysis of data which are qualitatively different from traditional analysis methods are now at a realizable stage.

"Integration of computational techniques and information analysis techniques that are related to materials research will reduced the materials development cycle from its current 10 to 20 years to 2 to 3 years," according to a proposal written in"Integrated Computational Materials Engineering," issued in 2008 by the National Research Council of the National Academies of Sciences. Having accepted this proposition, the American government initiated a national effort called the "Materials Genome Initiative" in 2012. Regarding specific programs, for example, the NSF started "Designing Materials to Revolutionize and Engineer our Future (DMREF)", while the NIST started "Building the Materials Innovation Infrastructure: Data and Standards" in 2012.

Turning to the present state of affairs in Japan, although simulation analysis and prediction are in progress in materials research, prediction and visualization by exhaustive computation or machine learning, using data or data sets and computational capabilities, are not utilized at all. Moving forward, an urgent collaboration between experimental scientists and computational scientists as well as data scientists is demanded.

Major expected research subjects and scientific methods are as follows:

(1) The topics to be solved by materials researchers include: "Extraction of rules for structure and physical property correlation and clarification of complicated phenomena, etc. by the analysis of a wide diversity of massive data," "Prediction of properties and structure using massive data (design of experiments),""Search for materials (structure) using optimization techniques, etc.," "Multi-scale modeling," "Advancement of mathematical models using high-dimensional data," and "Visualization of material space or analytical data (Method: Holistic visualization or highlight visualization; Target: raw(primary) data, such as images and spectra, and processed(secondary) data, such as numerical groups in papers)."

(2) As data scientific methods, "Machine learning," "Bayesian inference," "compressed sensing (sparse modeling),""data assimilation," "inverse problems," "mathematical modeling," "optimization," and other interpolation or extrapolation methods should be applied to the above (1).

It is frequently difficult for only one laboratory to perform this data-driven approach; thus, the involvement of more than one person and group with a variety of specializations is essential. In order to promote the above-mentioned research subjects, it is therefore also necessary to build an open platform for materials informatics to serve as a common ground in which all of the persons involved in materials innovation, from the academic sector to the industrial sector, can easily use all data.

The roles of the Japanese government and research institutes to advance the above-mentioned efforts are as follows:

◆ Role of the Japanese government

In Japan, most of the measuring equipment and computers used for research, as well as simulation software and databases are foreign products, and the status of Japan is as a user, internationally. The harmful influence of this situation is not limited to an economic problem in which Japan purchases products from countries of manufacture at high prices. Because software is made so that researchers in the countries of manufacture can use it to their advantage, Japanese researchers are at great a disadvantage in the use of such software to obtain the results. For example, consider the situation in which a special analysis may be conducted using certain software, so that special visualization is conducted, and the efficacy of a given medicine can be determined. Now, further consider that this software may be commercialized and exported without revealing this special analysis method to persons other than the software developer and the university researchers involved in the collaborative research. In this case, the Japanese researchers who have to use that standardized software to conduct research will be greatly handicapped, from the outset.

The construction of infrastructure, such as database construction and the commercialization of simulation software equipped with new algorithms, does not tend to receive suitable support because of the nature of a competitive fund that focuses on the promotion of basic research and practical application of research results. The Japanese government should not expect short-term results, but should provide continuous support from a long-term standpoint, and the preparation and sharing of, not only of a hardware infrastructure, but also an "intellectual foundation (software infrastructure)" are its urgent duty. Thus far, special attention has been given to the development and commoditizing of (large) advanced measurement research facilities and equipment. In addition, the preparation of an information infrastructure technique to cope with big data is at an initial stage. However, there is no environment in which researchers can use a wide variety of data on materials, which is inseparably related to or more valuable than the above-mentioned efforts. Accordingly, the immediate construction of such a system is an urgent task.

◆ Role of research institutes

To build an open platform for materials informatics, continuous contributions from universities and public research institutes are essential, along with financial support from the Japanese government. With the aim of implementing integrated and comprehensive research on materials informatics, they should build the framework for a research system to promote close cooperation among researchers in materials process, measurement, and computation in materials science to create a new current of scientific and technological research via cooperation and integration with data science. To accelerate materials development, the materials research community needs to share data sets, simulated empirical formulae, and advanced algorithms across study fields.

The most important activity is to build an evaluation system to allow the academics themselves to discover and encourage new-risen and integrated areas, as written in our proposal, to positively recruit the necessary motivated persons, and to provide incentives.

Concretely speaking, we propose that the following activities should be conducted as related programs.

● Launch of a data-driven research program

A feasibility study (FS) program for a method for data exploration and analysis will be conducted to establish and advance this method, and result cases will be created. In particular, a program which involves basic collaborative proposals by materials and data scientists should be initiated with an annual research fund of approximately 10 to 20 million yen. Because collaborative proposals involving different research fields are demanded, it will be necessary to provide a longer application period than usual, in order to guarantee a cross-boundary exchange period through academic conferences and workshops.

● Establishment of a data integration/research & development center

A core site for data integration and research & development will be established to determine a data management policy (i.e., the type and range of data to collect) and to manage data and tools. This site will provide with the functions of a service center, to promote the construction of a materials informatics system in which research institutes and universities introduce the concept of Lined Open Data (LOD) and use standard data formats, such as the Resource Description Framework (RDF)/XML to exchange information for application to materials development.

*1: “Design” in our proposal means the examination of a function or property demanded for a material, and the determination of composition to realize it as a specification. This is an engineering concept, at the opposite end of the spectrum from “analysis” as a scientific means, and is sometimes called “synthesis.” Key factors describing substances in materials R&D are multilateral, such as texture, crystal structure, chemical composition, electronic structure, and magnetic structure, and these are determined in consideration of the degrees of freedom (such as size, electric charge, spin and orbital) of each element. “Design” in an analytical manner is impossible; accordingly, a trial-and-error approach based on experience and intuition is usually required. Our proposal brings forward a systematic design method to surmount the dependence on the traditional method based on experience and intuition.

*2: “Data science” in our proposal is a generic name for techniques to discover characteristic patterns from complicated or massive data to gain effective knowledge, and includes engineering techniques. Typical examples of data science include data mining and machine learning. Among information science, statistics, and applied mathematics (or computer science or mathematical science), areas related to data processing are applicable.

*3: Although the number of elements dealt with in materials science is approximately 80, the number of combinations of these elements is approximately 3,000 in a binary system and approximately 80,000 in a tertiary system. However, the number of possible compounds is greatly increased if composition ratios are considered. For example, in the case of a compound AxByCz, where x, y and z are integers and $x + y + z = 10$, the number of combinations is 100, with 8 million for the entire tertiary system. Even if the composition is the same, crystal polymorphism frequently occurs to yield many types of structure, so the number of combinations increases.

The number of data on up to tertiary inorganic compounds listed in the Inorganic Crystal Structure Database (ICSD) is 76,000 at present, and if duplicated data, which consists of plural data for each compound, are not counted, the number of inorganic compounds with experimentally-known crystal structures is less than 50,000.

## 57. Development of a Novel Storage System for Stable, Long-Term Preservation of Digital Data【Executive summary in English】

As we move further into the era of information explosion, the amount of digital data being created and stored is expected to skyrocket. This proposal, entitled "Development of a Novel Storage System for Stable, Long-Term Preservation of Digital Data", discusses the development of a new storage system that not only preserves digital data stably over a long period, but also guarantees accessibility and comprehension of the stored data. Target term of the first stage is 100 years, and that of the second stage may be 500 - 1000 years, based on the achievement of the first stage.

Efforts to develop electronic technologies to support today's digital information infrastructure are concentrated in the development of information processing technologies, and little attention has been paid to the need to develop information preservation technologies. For this reason, a significant gap exists between information processing technologies and information preservation technologies, a gap that could disrupt continuity in human society. Arguing that the development of a reliable, ultra-long-term storage system is necessary to reduce this gap and avoid relevant potential risks, this proposal discusses important development-related issues and suggests measures to promote such development.

In order to realize the functions and performance required for a ultra-long-term storage system, it is necessary to solve all of the R&D issues associated with different technical layers, which include a product business (application software) and an information system (standardization and an operating system) in the uppermost layer; the hardware system; circuits and design; devices; production processes; and materials in the bottom layer. Solving such issues requires R&D efforts that ensure cooperation and consistency not only within each technical layer, but also between the different layers.

Concrete issues associated with developing the product business include identifying the conditions for widespread adoption, examining the development strategies to be adopted, and exploring which business model should be followed. The issues associated with developing the information system include creating the scheme for metadata written on the chip, guaranteeing the permanence of the data formats to be used, examining the file systems to be used, and investigating the possibility of standardizing these aspects. All these issues are important for guaranteeing readability and comprehension of the stored data. Furthermore, issues related to the storage system and the circuit system include introducing the concept of adapters and developing technologies to prevent data tampering, while the issues related to processing and device systems include determining which technologies can guarantee the reliability of a chip as a whole, developing processing technologies suitable for ultra-long-term storage, and developing package technologies. Lastly, issues regarding the materials to be used include developing non-degradable materials for wires and pads and understanding material degradation mechanisms.

Today, migration of data as well as migration of entire systems is conducted regularly for the long-term preservation of digital data. However, it is possible that the costs of data preservation, including the costs of data migration, will rise significantly, and that continuing data migration activities will be difficult in the future. Against this background, migration-free, maintenance-free data preservation will ultimately be essential. The purpose of this proposal is to solve the problems associated with data preservation. If the recommendations presented in this proposal are realized, the size of the market for the new storage system is expected to range from 20 to 30 trillion yen given the market size for current optical disk drives which have similar use (equivalent to several percent of the amount of "digital-born" content created and stored).

With regard to the promotion of R&D, since the importance of this field is not necessarily commonly recognized at present, it will be important to, firstly, expand the community of people associated with this field. This can be achieved by gathering together not only engineers but also experts in various fields like social science, culture, and business models and by organizing research seminars and other types of meetings. Subsequently, a national strategy should be created based on the common ideas developed by the participants in this field, and appropriate projects that take globalization into account should be launched as soon as possible.

## 58. Development of New Materials and Innovative Devices Using Atomically Thin 2D Functional Films【Executive summary in English】

This proposal, entitled "Development of New Materials and Innovative Devices Using Atomically Thin Two-Dimensional Functional Films," is about research and development (R&D) of new materials, innovative devices, and nanosystems[1] that use atomically thin two-dimensional functional films such as graphene which has attracted attention in recent years.

An atomically thin two-dimensional functional film is defined as a functional thin-film material whose surface or interface has a two-dimensional atomic crystal structure or an equivalent two-dimensional electronic state. Such films have properties and structures different from those of traditional bulk materials or simple thin films, are capable of having new functions or functions superior to those of traditional films, and are anticipated to contribute to the development of new materials and devices. The proposed R&D is expected to lead to significant reduction in power consumption and device size, which is needed for next-generation electronic devices and systems, and to the creation of new functions incorporated into such systems. These potential outcomes can strengthen the international competitiveness of Japan's electronics industry and other industries related to the production of electronic devices and nanosystems. Moreover, it is hoped that the proposed R&D will lead to the discovery of new material functions in basic science, to integration of academic fields related to functional thin-film research, and to medium- to long-term training of young researchers who will become international leaders in this field. At present, the field is indeed at a stage where research activities are being intensified in Japan and overseas, and thus it is essential to implement national R&D policies early so that Japan can play a leading role in this field.

Two main R&D-related challenges are proposed: (1) creation of fundamental technologies for innovative devices with atomically thin functional films that serve application needs and (2) research on the functions of atomically thin films with novel structures and establishment of scientific principles in device design that will contribute to advancing technologies offered to the market. A multilayered approach to R&D is necessary that responds to both the first challenge, which is based on clear user needs, and the second challenge for which such needs are met through the provision of relevant technologies. Application-oriented R&D is aimed at the practical use of graphene and other materials in transparent electrodes, conductive thin films, LSI wiring, various sensors, and high-speed electronic devices. Research topics related to technologies offered to the market include various component technologies associated with atomically thin films, particularly synthesis technologies; crystal growth technologies; manufacturing technologies; measurement, analysis, and evaluation techniques; and exploratory theoretical analysis and simulation methods.

Achieving the goals in this proposal requires several measures for promoting strategic R&D.

As international competition in R&D becomes increasingly severe, this proposal suggests utilizing the Tsukuba Innovation Arena (TIA)[2] as a common infrastructure for improving the efficiency of R&D investment to the greatest possible extent and for increasing the speed of pre-application development. Through research projects centered on the TIA (which has 100 corporate nanoelectronics researchers and 300 researchers overall), and through publicly offered projects sponsored by JST and other organizations, it will be possible to promote R&D projects that are conducted cooperatively by industry, universities, and independent administrative agencies. With regard to the details of projects, it is necessary to strongly collaborate with the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Economy, Trade and Industry, and relevant independent administrative agencies, to incorporate opinions from industry, and to secure industry's commitment to efforts for realizing the practical application of technologies.

As for the promotion of R&D, execution of the aforementioned multilayered R&D is expected to bring about incorporation of techniques gained through the development of applied technologies into basic research and will consequently lead to the creation of game-changing technologies.

As for R&D investment, this proposal suggests that integrative research be promoted somewhat forcibly by designing rules that require interdisciplinary collaboration among applicants to a publicly offered program, for example, between a team that approaches problems from a physics standpoint and a team that approaches problems from a chemistry standpoint. Also, in order to promote training of researchers which will be needed in the field of atomically thin films, a funding system must be established that will seamlessly connect the results of academic research projects receiving

Grants-in-Aid for Scientific Research to objective-oriented basic research supported by, for example, the JST Strategic Basic Research Programs and then to programs for the development of practical applications sponsored by the New Energy and Industrial Technology Development Organization and other organizations.

In the case of graphene, Japan's R&D policy is less active relative to those of European countries and the United States, and it is generally considered that Japan makes only a small contribution in this field. However, Japan is a leading country in the field of materials science. Since cooperation and collaboration among physicists and chemists is essential to research on atomically thin functional film, Japan's future efforts should include promotion of large-scale national projects and programs that not only are based on research integrated with related fields and "vertical" cooperation with applied fields, but also should include researcher training and international cooperation. The goal is to realize ultra-low-power electronic devices and systems with new materials, to achieve energy and resource conservation, which is strongly needed to create tomorrow's sustainable society, and to meet societal expectations.

[1] A nanosystem is defined as a part, device, or system that is socially recognizes and is capable of providing high-level functions contributing to the solution of important issues as an aggregate/integration/unification of component technologies in the fields of nanotechnology and materials science and other fields.

[2] The TIA is listed as one of the factors in science and technology that contribute to growth in the New Growth Plan approved by the Cabinet in 2010 and satisfies the description of the place for industry-academia-government cooperation promoted in the Fourth Science and Technology Basic Plan. Also, some of the programs promoted by the TIA are included in the Action Plan for the 2012 Priority Measures in Science and Technology.

## 59. Next-Next-Generation Rechargeable Batteries and Electric Storage Device Technologies "Key Devices for Low Carbon Society and Decentralized Energy Systems"【Executive summary in English】

One of the central challenges in green innovation is the development of technologies for storing electric energy. Focusing on such technologies and taking a long-term view for 2030 and beyond, this proposal advocates an R&D strategy for creating next-nextgeneration rechargeable batteries and electric storage device technologies, which will be significantly superior in terms of performance, functionality, and cost effectiveness to the various types of rechargeable batteries that are currently being researched.*

Following the Great East Japan Earthquake on March 11, 2011 and the accident at the Fukushima Daiichi Nuclear Power Plant, it is imperative to comprehensively reexamine Japan's future energy policy as well as the relevant strategies for energy R&D. From around 1 year before the earthquake, the Center for Research and Development Strategy (CRDS) of the Japan Science and Technology Agency (JST) has been considering and discussing the R&D strategies for power storage technologies of the future, with the participation of top researchers and engineers from both academia and industry. Taking the current situation into consideration, the Center has now summarized this work into a proposal on future challenges in R&D and issues in promoting R&D. This proposal focuses on rechargeable batteries and electric storage device technologies, which are considered key in drastically reducing fossil energy use in the transportation sector and in realizing decentralized energy systems aimed at the efficient use of new energies and the securing of emergency power sources. Such batteries and device technologies can be used in the following: (1) automobiles, other types of vehicles, and transportation machines (large capacity, transportable); (2) stationary decentralized energy systems (large/super-large, stationary); and (3) mobile devices (small capacity, portable). This proposal mainly discusses the first two areas. As future innovative electric energy storage will not necessarily take the form of current rechargeable batteries, this proposal also considers the possibility of creating new and different storage devices.

Conditions surrounding society and the industries and academia involved in battery technologies are drastically changing. Japan has traditionally maintained an internationally advantageous position in the field in terms of comprehensive technological and industrial competitiveness, but with increased demand for batteries and an expansion of the market, this position is being threatened by intense competition from Asian countries that have cost advantages. As a result, the share in the international market of Japanese manufacturers of batteries and related parts and materials has gradually declined, despite being still at a top level. Also, in terms of the number of research papers published in relevant academic fields, Japan's position has been falling as other countries are strategically implementing R&D policies. Although Japan is currently promoting the development of next-generation rechargeable batteries through active implementation of policies by the Ministry of Economy, Trade and Industry (METI) and New Energy and Industrial Technology Development Organization (NEDO), the country cannot be said to be sufficiently prepared for the development of next-next-generation technologies further into the future.

Industry is continuing to lead the development of batteries for electric automobiles in response to strong demand in the market. It is hoped that the results of such efforts will lead to the development of stationary storage batteries that afford a stable electric power supply. This will be crucial when natural energy generation, such as photovoltaic generation and wind power generation which have unstable output, is introduced. Moreover, such small decentralized power sources acting as emergency power sources can play an important role in maintaining a safe and reliable social system. In any event, such batteries must be safe and small, have high capacity, and be of significantly low cost. At present, an energy density of 700 Wh/kg is the goal set in order to achieve widespread adoption of electric automobiles (METI 2006). This goal cannot be achieved with an extension of the current lithium-ion battery technology (which is said to have an upper limit of energy density of 250–300 Wh/kg). As there is no prospect of achieving such a goal, including the need for safety improvement, through the work currently being undertaken in various development projects, we must strengthen basic research activities, such as those focusing on clarifying basic phenomena, constructing theoretical models, and creating new concepts based on them, as well as strengthen R&D activities aimed at achieving realistic goals of the moment. The battery is a comprehensive system consisting of various technologies and, at each stage from basic research through to practical application, it requires technological development in a wide range of areas, encompassing materials, devices, circuits theory, system interconnection, and power management. It is important, therefore, to connect the roles played by industry, academia, and government in solving the technological issues involved.

The metal-air rechargeable battery, s-block metal rechargeable battery, and polyvalent cation rechargeable battery are the types of batteries we believe will emerge after the advent of the next-generation batteries currently being researched and developed. Shown below are the challenges in R&D that must be met in order to create core technologies for the future, including electric storage device technologies based on new structures and new concepts. To meet these challenges and achieve practical application of next-next-generation, innovative (ubiquitous) rechargeable batteries and electric storage devices, it is necessary for Japan as a nation to create a comprehensive system for research and promote it strategically. In particular, the following activities will be significant in discovering the seeds of innovations that will far surpass current expectations: improving the systems of basic/core research for understanding various phenomena, promoting cross-field integrative research, providing a continuous investment of resources, engaging in long-term training of researchers, and connecting the roles of basic/core research with application development research.

The important future challenges in R&D will be divided into three fields.

1. Development of new materials (development of new electrode materials; optimal design and control of nanoscale, three-dimensional structures near the interface of electrode materials; development of new electrolyte materials that achieve a balance between safety and high voltage; development of new separator materials)
2. Development of new technologies for storage device systems (development of technologies for combining new materials; development of design and manufacturing technologies for macrosystems based on an understanding of nanoscale phenomena; development of technologies for safety systems)
3. Understanding of cell reactions and development of theories and models (direct observation of cell reactions and development of measurement technologies; understanding of performance decline and degradation mechanisms; development of models of cell reaction theories; research on the application of computational science)

Battery research in Japan has traditionally made progress mainly in the field of electrochemistry. In contrast, this proposal emphasizes the field of physics, especially integrative research conducted by specialists in theoretical physics and solid-state physics, synthesis chemists, and experts in molecular design. Moreover, the collaboration of researchers specialized in measurement technology and computational science is required, as remarkable progress has been seen in both fields in recent years. It is hoped that the integration of these fields will be actively promoted.

Following the Great East Japan Earthquake and accident at the Fukushima Daiichi Nuclear Power Plant, Japan has experienced limited energy supply. This has dealt a serious blow to industry and to people's lives. Decentralized energy systems were planned before the earthquake disaster as a way of contributing to the realization of an energy-saving society in the future. Today, the importance of these systems is even more pronounced and there are high expectations for their early realization. It is essential, therefore, to develop high-capacity, high-density electric storage devices that are so advanced that they are noted as 'next-next-generation'. Although industries facing severe international competition are making investments in R&D activities for next-generation products, there is a lack of strategic investment in the creation of basic/core technologies that will lead us into the next-next-generation. In battery R&D especially, which takes time, strategic R&D with a long-term perspective should be promoted by universities, public research institutes, and industry, with the first two types of organizations playing a central role.

* Next-next-generation rechargeable batteries and electric storage devices This proposal regards batteries with an energy density 3 to 5 times higher than that of the current lithium-ion batteries as "next-generation rechargeable batteries" and batteries that have greater potentials and are expected to be realized for practical use in 2030 or later as "next-next generation rechargeable batteries and electric storage devices". The latter includes the lithium (metal) air rechargeable battery, all-solidstate lithium rechargeable battery, s-block metal rechargeable battery, polyvalent cation rechargeable battery, new types of rechargeable batteries, batteries based on new concepts, and electric storage devices such as capacitors.

## 60. Nanotechnology - Grand Design in Japan ～ Key technology for solving Global Issues ～

This report focuses on “nanotechnology” as one of essential R&D areas for solving global social problems, and comprehensively discusses on the following issues: （1） clarification of the scientific and technological aspects of nanotechnology and its positioning with respect to other disciplines on a total science-technology map, （2） analyses of national nanotechnology initiatives of main countries in the world, including warnings and suggestions for the future public investment to this area in Japan, and （3） concrete proposal of new nanotechnology initiative for solving global issues.

Main conclusions include the followings:

（1） The scientific and technological area called as “nanotechnology” is evolved through three different stages ; the first stage / progressive advancement of each independent nanotechnology （“progress-nano”）, the second stage / fusion of advanced nanotechnologies out of various S&T areas in a interdisciplinary way （“fusion-nano”）, and the final stage / creation of new function as a system by assembling various advanced and fused nanotechnologies （“system-nano”）.Through this serial and parallel evolution of nanotechnology characterized by the above three stages too-much specialized and diversified disciplines are synthesized in a unified manner, giving rise to “Functions Design” for the global issues. “Functions Design” symbolizes a restoration of true Engineering that nanotechnology drives, and provides a strong weapon for solving future problems and creating innovation.

（2） Since 1980s Japanese government has continued to make R&D investment to the area of nanotechnology and materials, and maintains high scientific as well as technological potential in this area up to now. However, quite recently, as far as public investment to this area is concerned, not only US and EU but also China and Korea exceeded Japan （if compared by PPP in 2007）. It is likely that Japan will lose her national benefit if the government hesitates to make future funding to the area of nanotechnology. Tangible and intangible asset such as R&D potential, networks of user facilities and human resources which have been piled up for the past several decades should be inherited as a legacy without a delay for setting up the new strategy in terms of the 4th S&T Basic Plan to be initiated in the fiscal year of 2011. As for the education and the human capability development it is strongly desired that not only the government sector but also the academia sector should make their own efforts to prepare their long-term future plans.

（3） Public investment policy in the 2nd （2001-2005） and the 3rd （2006-2010） S&T Basic Plans of Japan has been based on so-called “Priority R&D Areas”, but now is going to be shifted to“ Social-issue Targets” on which a total scenario of the 4th S&T Basic Plan （2011-） will be discussed. Such a big change in a S&T policy, in general, should be justified by logical and quantitative evidences deduced from a systematic review of the total 10-year S&T Basic Plans spending roughly ¥40T （~US$370B）. In any cases, independent of whether S&T policy is based on “Priority R&D Areas” or “Social-issue Targets”, most important systems for improving investment efficiency in the area of nanotechnology are an implementation system where interdisciplinary interaction and academia-industry communication are promoted, and a coordination system for encouraging inter-ministry collaboration. Therefore, it is important to describe a whole S&T Plan as a matrix consisting of “Social Issues” and “R&D Areas”, and to implement the whole plan as one body. “Green Nanotech” for Energy &Environment （Green Innovation ）, “Nano-Bio” for Health and Medical Issues （Life Innovation ）, and “Nanoelectronics” for maintaining future global competitiveness of Electronics Industry are proposed as important R&D areas in the field of nanotechnology. Priority areas in the coming Basic Plan, different from “strategic important R&D areas” in the 3rd S&T Basic Plan, should be funded according to their prescribed ratios of total amount of investment. Namely, investment ratio of each priority area should be authorized by the government in advance in order to guarantee the quantitative execution of the strategy, which is similar to the system of Program Component Areas （PCA） in NNI in the United States, and those of Korea and Taiwan as well. This kind of funding policy is quite important for constructing infrastructure like user-facilities network, and also for promoting activities of EHS and ELSI towards responsible development of nanotechnology.

Chapter 1 entitled “Nanotechnology in Society” presents a basic idea of nanotechnology in society suffering from global issues. Nanotechnology as one of interdisciplinary technological areas inevitable for solving global issues, its definition and properties can be understood within a framework of the evolution process described in terms of three different stages of nanotechnology; “progress-nano”, “fusion-nano”, and “system-nano”, which has been evidenced on the basis of historical steps of nanotechnology. Through serial and parallel evolution of nanotechnology whole scientific and technological areas, which are too much diversified and become invisible at the present time, are reconstructed and integrated into a new concept “Functions Design” for the solution of global issues, producing and nurturing new S&T areas such as Green Nanotech, Nano-Bio, and Nanoelectronics. It is demonstrated that Japan, as one of nanotech-advanced countries, has made essential contribution to this field for more than a half century.

Chapter 2 “International trends and Japan’s problem” provides an overview of national nanotechnology initiatives running after the year of 2000 in more than 20 countries including US, EU, Japan and some Asian countries, activity comparison among those countries with regard to public investment, COE’s of R&D, education / human capability development, and social acceptance issues, by which current status of Japan and her future problems are made clear. China and Korea increase their total public investment to all S&T areas intensively while Japan does not so much. Also, in the field of nanotechnology, annual investments of US, China and Korea already exceeded that of Japan if each currency is evaluated using purchasing power parity （PPP）. On the other hand, current global trends of nanotechnology are characterized by the following items; （1） big expectation to nanotechnology for its major contribution to global issues, （2） participation and growth of Asian countries and BRICs in this field, and （3） rapid increase of commercial nanotech products. DOE of U.S. initiated 46 Energy Frontier Research Centers （EFRC） in 2009 after 7-year activities of workshops where important use-inspired fundamental research subjects were selected deductively in order to meet technological requirements from the future social-use targets of Energy, Health and Environment. Consequently, more than 80% of subjects of 46 EFRC’s turns out to be in nanoscience and nanotechnology. All of those global trends clearly indicate that nanotechnology will play a role of “innovation driver” for solving social issues, which seems to be accepted as a world common understanding. Although Japan still maintains high levels of scientific papers, patents and industrial parts and materials in spite of slow increase of public investment, “fusion-nano” and “system-nano” are essentially important for working out a solution for global issues, and it is very likely that Japan will lose her national property if she stops public funding to this field under rapid growth of Asian countries and BRICs. Other relevant problems of Japan’s nanotechnology initiatives are pointed out: incomplete funding to user-facilities network and research hub centers, less incentive for global collaboration of young researchers and academia as well, and the absence of “one-stop international gate" of social-acceptance issues of nanotechnology.

Chapter 3, "Nanotechnology – Grand Challenge", presents how to set up the coming public R&D policy after 2011 and how to operate nanotech-related initiatives by discussing the grand challenge of nanotechnology in a more concrete way. Intermediate reports on the 3rd S&T Basic Plan （FY2006-2010） prepared by independent ministries unanimously describe that the coming S&T plan should be organized on the basis of "Social-issue Targets" rather than "Priority R&D Areas" because the latter approach adopted by the 3rd Basic Plan has a tendency to cause vertical inter-area barriers in discussion as well as policy setting. However, up to now, any logical and quantitative evidences for such vertical barriers among four priority promotion areas have not been reported, and also systematic review on the 2nd and 3rd S&T Basic Plans spending roughly ¥40T （~US$370B） for the past 10 years has not been done as yet. Even if there could exist any vertical inter-area barriers among Project Teams of 4 Priority Promotion Areas of the Council of Science and Technology Policy （CSTP） in the Cabinet Office, Japan, it is necessary to clarify whether those barriers are caused by an essential defect inherent to the approach of "Priority R&D Areas", or simply due to the lack of coordination by CSTP, or due to more fundamental reason originated from the decision-making process of the government with respect to inter-ministry collaboration. According to two different studies based on quantitative analyses of patents from the 8 different R&D areas it is most probable that the innovation comes from the field of Nanotechnology/Materials in the future. Most important mechanisms for increasing the efficiency of the investment to the field of nanotechnology are those for stimulating interdisciplinary interaction among people coming from different fields and also academia-industry communication, and for encouraging and giving incentive to inter-ministry collaboration in the government sector, independent of any scenarios on future S&T basic plans. Priority areas in coming S&T plan after 2011, which correspond to the "Strategic Important R&D Areas" of the 3rd S&T Basic Plan, should be funded according to their pre-determined allocation ratios of total budget of the initiative in order to guarantee the quantitative execution of the strategy. In this sense, such allocation ratios should be authorized in advance by the government, which has been already adopted by NNI of U.S. in terms of Program Component Areas （PCA） , Korea and Taiwan as well. The lack of quantitative or numerical indication of allocation ratios of budget in the case of the 3rd S&T Basic Plan of Japan resulted in around 2.5% of allocation to users-facilities network （Nano-net） , which is much lower than those of U.S. （~15% ）, Korea （~20%）

and Taiwan （~15%）. Nanoscience and nanotechnology together with materials science continuously promote “fusion of scientific disciplines”, which brushes up the potentiality of the fundamental research for solving global issues. Furthermore, nanotechnology plays an important role of combining various technological areas too, such as energy, environment, ICT, and biotechnology. Through such “fusion & evolution of technological areas” Green nanotech, Nano-bio and Nanoelectronics are produced and nurtured as new technological areas, hopefully giving birth to new industry that will contribute to the solution of global issues. “Fusion of scientific disciplines” and “fusion and evolution of technological areas” should take place in the same resonant field where a plenty of information is circulated in real time. Exploration of new materials, design of functions, and computational science are emphasized as key factors for connecting “nano” with “system”. Various relevant systems are proposed in order to promote and accelerate interdisciplinary research projects, such as user facilities and R&D centers, education / human resource development, industry-academia-government collaboration, inter-ministry activities, new funding policy, social acceptance of emerging nanotechnology, international cooperation, standardization, and intellectual property right.

## 61. Molecular Technology “The creation of novel functions from molecular levels” -To assure sustainable society by fusing multi-disciplinary fields-【Executive summary in English】

“Molecular technology” is a series of techniques to exploit fully features of molecules to create the desired functions by designing, synthesizing, operating, controlling, and integrating molecules on the basis of scientific findings in fields of physics, chemistry, biology and mathematics. Molecular technology is a general term of technologies aiming at free control of molecules in intent to create new materials, new devices, new processes, and useful materials, etc. This initiative proposes promotion of research and development by embracing “Molecular technology” from the cross-cutting perspective and by providing the comprehensive framework. Furthermore, this initiative leads to a noble development because researchers of various fields without any connections can reconsider mutual works on the common basis of “Molecular technology”.

In the conventional molecular science field, the similar functions were obtained by copying artificially natural molecules identified through discovery and analysis of various molecules in the course of observing and exploring through the nature. Recent new trend, however, is not to seek a model in the nature, but is to design the target functions first, followed by obtaining the substance compatible with such functions, as is observed in several research and development cases. Behind such a trend are the rapid performance upgrade of computers used in molecular designing and reaction simulation, the rapid progress of in situ process monitoring technologies for real-time measurement and analysis of chemical reaction process by means of X-rays and electron beams.

We propose here for funding the review of rapidly-advancing molecular technology as a whole from six cross-cutting technical aspects. They are the molecular design and creation techniques, molecular conversion and processing techniques, molecular electronic state control techniques, molecular shape and structure control techniques, molecular assembly and complex control techniques, and molecule・ion transport control techniques.

The mainstream is “funding” to solve issues separately in fields, each with individual application theme, such as “solar cell”, “drug discovery”, etc. Funding is intended to review technical issues presenting bottlenecks for application according to the concept based on above six cross-cutting aspects, thereby allowing researchers of various fields to challenge the study while being equipped with common scientific concepts. For such purpose to be achieved, it is essential to take the interdisciplinary approach. Namely, researchers from chemistry, physics, biology and mathematics are to coordinate and interlink.

If these R & D achievements are to be developed into “Molecular technology” in each application field, it is important first to establish the cooperation system between the engineers engaged in device realization and in application fields（ drug development, etc.） and the industries in charge of mass production and marketing. Through merging of cross-cutting technical fields in the established cooperation system, R & D achievements must be established as individual molecular technology.

This initiative must be cooperatively driven by both MEXT and METI. Moreover, related scientific societies such as The Chemical Society of Japan, The Physical Society of Japan, Japan Society of Applied Physics, The Pharmaceutical Society of Japan, The Molecular Biology Society of Japan, etc, are needed to promote the interdisciplinary fusion by the removal of walls existing among societies.

As described so far, R & D in the molecular technology is difficult to move forward solely by the independent findings of conventional scientific fields, such as chemistry, physics, biology and mathematics. What is important is to take up and overcome the bottlenecks in applications as common issues based on the interdisciplinary merged fields. Note that cross-cutting funding covering the whole of molecular technology has not yet been implemented inside and outside Japan. It may be that, by implementing funding early in Japan, we may take the leadership of the world in this field.

In conclusion, the contents of this initiative must be started as early as possible and implemented within the medium- to long-term scope.

## 62. Design and Utilization Technology for Controlling Spaces and Gaps in Advanced Materials -To assure a sustainable society by fusing multi-disciplinary fields-【Executive summary in English】

A strategic proposal "Design and utilization technology for controlling spaces and gaps in advanced materials" consists of a comprehensive package of scientific methodology and implementation technology to explore and develop cutting-edge functional materials and devices. The materials are named "spaces and gaps controlled materials (SGCM)" that include nano-porous, meso-porous, nano-tube, and layered compounds synthesized by self-organization process. This strategic project proposes R&D subjects to fully cultivate the potential of SGCM in terms of basic science and practical development as well. It also proposes an effective network approach for research-enhancing collaborative organization and research funding system as well. The execution of the proposal provides challenges and opportunities to create a new academic field and to achieve solutions for various difficult global issues in the field of environment, natural resources and medical health we are facing, paving the way for the sustainable society.

"Spaces and gaps" refers to free spaces embedded in topological networks composed of constituent atoms and chemical bonds connecting them, which is considered as a key component to understand mechanism for emerging functionalities of materials in various aspect, specifically dimension of the space. For example, nano-sized spaces create material functionalities by controlling physical and chemical interactions among the spaces and surrounding walls. Further, macro-sized spaces relax mechanical stress inside the materials, for instance, to stabilize whole bulk structures.

It has been clarified recently that configuration, chemical bonding and energy states of constituent atoms around the "spaces and gaps" primarily define performance of the materials such as efficiencies of energy conversion between different types of energy including optical, electrical, thermal, chemical and mechanical ones, and mass transport capability. With an extension of scientific concept of the "spaces and gaps" to what includes interface and surface, an academic platform is provided where fusion of multi-disciplinary fields takes place, leading to the creation of a new scientific field. The concept accelerates seamless connection of seed-oriented fundamental research with need-driven development.

Recent progress in design flexibility and controllability in materials science enables to develop new advanced materials, whose functions have been hardly realized by conventional techniques developed for bulk materials. In particular, discovery and development of innovative materials have attracted much attention in the fields of environment, natural resources, energy, chemical separations, catalytic reactions, optoelectronics, superconductivity, construction materials and bio-materials. Enhancement of performance of these materials is also important for “biodiversity” and “sustainable society”. The generalized concept of the space and gaps works as a guiding principle to achieve above mentioned target. These concepts and procedures for material development, together with necessity for elementary technologies contribute to providing solutions to the global issues, resulting in strengthening international competitiveness of our country.

This strategic program consists mainly of the following three subjects:
A: Design and synthesis of SGCM: Maximization of functionalities
B: Implementation technologies of SGCM: Promotion of applications
C: Common basic technologies: Measurement, analysis, clarification of scientific mechanism, and computer simulation

Subject A is the seed-oriented research for designing new structures and functionalities, and synthesizing SGCM. On the other hand, Subject B, the most distinct feature of this strategic program, covers a set of implementation technologies, which is necessary for the application of elemental seed technologies in Subject A to practical developments in order to meet the social needs. Examples of Subject B include technologies related to realization of microscopic functionality in macroscopic scale, increase in robustness, mass production with high yield and speed, and cost reduction. This strategic program encourages proposal of an implementation technology itself to meet an individual social need. Subject C refers to common basic technologies for both Subjects A and B, consisting of measurement, analysis of chemical reactions, mass-transports, and other relevant phenomena in the nano-scaled “spaces and gaps”. Various kinds of measurements and analyses such as microscopes, diffraction measurements and computer simulations are inevitably important for this strategic project.

Smooth execution of the project requires synergy of multi-disciplinary fields through communication among those who are involved in different stage of efforts from exploratory research to commercialization over various technical fields. Those involved in basic and applied researches differ in their standpoints and final targets, which sometime causes various difficulties in communication due to the lack of common language. To eliminate these difficulties the strategic project proposes research funding system and research organization with a center of expertise surrounded by networked satellites, which promote fusion spontaneously among fundamental researches covering vertically expanding areas and target-driven developments spreading over horizontally diversified fields.

## 63. Strategic Planning of Materials Research and Development for Strengthening Industrial Competitiveness【Executive summary in English】

As a strategy to add a new direction towards specifically enhancing the global competitiveness of industries in the basic material researches carried out in Japanese universities, we propose the “Strategic Planning of Materials Research and Development for Strengthening Industrial Competitiveness”.

Researches in universities and institutions generally tend to be based on their interest, and they consider strategically insignificant for strengthening industrial competitiveness. On the other hand, though industries have large expectations for the basic researches in universities, they find difficulty in expressing a unified long-term strategy to universities, since they are compelled to value short-term profits and are competing with each other in the initial stages of technology development.

In order to overcome such situations, Center for Research and Development Strategy, CRDS, has developed “Strategic Planning on Research and Development for Strengthening Global Industrial Competitiveness” (see (1)), and applied it to the material development field. Furthermore, CRDS extracted the R&D issues which should be confronted with strategically in the future, by referring to the discussions from the bird’s eye view workshops in the “material science field” etc. (see (2) ). These issues are shown in the following table.

<table>
<tr><td>Industry Clusters</td><td>Industries for Energy or Environment</td><td>Industries for Natural Resource Development</td><td>Industries for Information-communication</td><td>Industries for Machinery and Precision Machinery</td><td>Industries for Transportation</td></tr>
<tr><td rowspan="4">Requests from each industry cluster</td><td>Hydrogen Generation and Carbon Dioxide Fixation</td><td rowspan="2">Diversification of Industrial Core Materials</td><td rowspan="2">Technology for Nano-electronic Devices</td><td>Human Alternative Robots</td><td>Fuel Cell Vehicles</td></tr>
<tr><td>Biofuels produced from Microalgae</td><td rowspan="2">Autonomous Decentralized Low Power Consumption Machine Systems</td><td rowspan="2">New Battery Powered Electric Vehicles</td></tr>
<tr><td>Acquisition and Assessment · Monitoring of Sustainable Water</td><td rowspan="2">Research and Development of Metal and Inorganic Materials extracted from Low-grade Secondary Resources</td><td rowspan="2">Packaging Technology for Nano-electronic Processing</td></tr>
<tr><td>Design for Environment (DfE)</td><td>Biological Adaptation·Autonomous Decentralized Medical Device Systems</td><td>Ultra-lightweight Cars</td></tr>
<tr><td rowspan="3">Material Technology – Important Elements Extracted from Interdisciplinary Industries</td><td colspan="3">Void Space Control · Utilization Technology</td><td colspan="2">Thermal Management</td></tr>
<tr><td colspan="3">Fusion Molecule Material Technology</td><td colspan="2">Interface · Surface Control and Formation</td></tr>
<tr><td colspan="3">Composite Materials</td><td colspan="2">Lightweight Solution</td></tr>
</table>

(1) Strategic Proposal "Developing a Method for Strategic Proposals for Strategic Planning on Research & Development for Strengthening Global Industrial Competitiveness? Creation and Development of ʻUmbrella Industriesʼ utilizing ʻElement Industriesʼ which Japan boasts" CRDS-FY2008-SP-10 from CRDS, JST.
(2) Report on the Results, Effects of Integration, Future Issues of Nanotechnology - the Bird's Eye View Workshop in the "Material Science Field" from CRDS, JST, CRDS-FY2008-WR-05.

The requests to the research and development from each industry cluster listed here comprehensively describe the themes which should be preferentially invested to further strengthen the future industrial competition. By making R&D investments according to these requests, we will be able to allocate funds more effectively and expect a speedier contribution from the specific basic research results. In extracting technical issues and element technologies, emphasis was laid on the following two perspectives of "public investment necessary to make strong industries stronger" and "upfront public investment for future industry competition" rather than "the ideal social image of the future".

Here we do not intend to leave the matter of the future R&D in each industry just to the industrial world, but have presented the critical items requested towards R&D addressed by the non-industrial world. By implementing these items, it will become possible to realize innovative breakthroughs, knowledge creation and so on, which will be difficult to expect directly from R&D in industries, thus it enables us to contribute to maintain and enhance the global competitiveness of Japanese industries.

In order to speedily connect R&D results by using industrial competitiveness, multi-faceted approaches need to be considered, and the fields of R&D or needed features and functions, are widely varied. This proposal aims at enhancing the connection between basic researches and industries by specifically presenting the requests to strengthen the industrial competitiveness to the researchers in universities, and so on, and facilitate conveying the requests from industries to the basic researches in universities which have not necessarily been done systematically.

## 64. Construction of Fundamental Technologies for Nanoelectronics ー Towards a technological breakthrough overcoming limitations in scaling, integration and power consumption reduction ー【Executive summary in English】

Proposed is the strategic promotion of seed-oriented nanoelectronics R&D based on a novel concept and emerging technology for penetrating the technological limit of CMOS aiming at the establishment of a long-term industrial platform in the future. For this purpose, academia and government-financed research institutes should lead their strategic R&D for exploring scientific and technological seeds for future nanoelectronics, in parallel with a scenario for new nanoelectronics as one of the future main industries.

Technologies for the down-scaling and integration of electronic devices will remain indispensable for meeting the demands of an exponential increase in information data that should be treated electronically. However, we are facing serious problems, such as an intrinsic physical limit of scaling, increasing dispersion of device parameters, and increasing heat power density caused by the integration. In order to overcome these difficulties, it is urgently needed to promote R&D, by making the best use of emerging nano-science and nanotechnology, in order to realize electronic devices based on novel principles replacing conventional CMOS, and to explore new materials applicable to the new devices. Since large public investments have already been made in this area not only in the US but also in the EU, it is urgent to accelerate the R&D activities of this area under the umbrella of a national strategic R&D plan.

Two specific R&D programs are proposed:

1) An R&D program for device operation and device technologies of novel-concept logic and memory devices for realizing high-speed operation, high capacity, low power consumption, and high reliability
2) An R&D program for exploring new materials enabling nanoelectronics devices and for demonstrating their technological feasibility for device application

R&D program 1) is concerned with novel logic devices using new state variables that can replace conventional logic devices that are basically operated by electronic charge, and also novel memory devices for ultra-high speed, ultra-high capacity, and ultra-low power consumption. R&D program 2) aims at exploring new materials necessary for the novel logic and memory devices. The aforementioned “new state variables” include, for example, spin, phase, polarization, and molecular configuration. These non-charge state variables have a possibility of realizing ultra-low power consumption and ultra-high speed operation, due to their characteristics without power dissipation and without signal delay originating in the capacitance. However, such performance has not yet been realized at present, and even the concept has not been verified for some state variables. Therefore, the proposed program includes high risks and high challenges, but the impact will be very high when the goal is achieved.

For the effective promotion of the proposed R&D, establishment of a research hub center, cooperative research of industry, academia and government, globalization, and personnel training and education should be evaluated as the achievement of the project. Specific promotion programs proposed are listed below.

(1) Establishment of a research hub center: Highly controlled facilities for device fabrication, processing, and characterization are indispensable for the proposed R&D of fundamental nanoelectronics technologies. The facilities should be constructed to adapt to the Japanese environment, referring to several global hub centers in the US and the EU.

(2) Cooperative research of industry, academia, and government: The results obtained in the R&D should not only be conceptual ideas, but also be guiding principles for the practical application in the real world. For this purpose, construction of a cooperative system of industry, academia, and government is desirable. Industry, academia, and government should collaborate for the R&D of various germinated seeds, and adjust the system according to the progress of the project.

(3) Globalization: An operation system that can promote participation of excellent researchers and active students, both domestic and from overseas, is essential for the proposed seed-oriented R&D.

(4) Personnel training and education: The most serious problem in the nanoelectronics field in Japan is insufficient human resources to play major roles in the next generation. The R&D should be promoted in a way whereby personnel training and education becomes one of the important achievements of the program.

Breakthrough or bypass of limitations in scaling, integration, and power consumption reduction will be difficult to achieve by the extension of current technologies, and thus a long-term approach for the investigation of novel-principle-based devices with new structures and new materials is essential. For the realization of the proposed program, governmental operation for maximizing funding efficiency, harmonizing with the current and planned programs across the related ministries and agencies, should be promoted.

## 65. R&D on "Flexible" electronics basic technology【Executive summary in English】

## 66. R&D on Basic Technologies for the Creation of New Electronics Featuring "Flexible, Large Size, Light Weight, and Slim"【Executive summary in English】

We propose a R&D strategy for the creation of new electronics featuring "Flexible, Large Size, Light Weight, and Slim" characteristics by integrating basic physics, chemistry and mechanics.
The devices and systems with "Flexible, Large Size, Light Weight, and Slim" characteristics include a wide range such as sensor, actuator, battery, display etc. In the case of display, for example, slim and flat type display is now taking up the large share in the market. However, the technology for "Flexible" function is not yet established. To achieve "Large size" display for future, "Slim" is indispensable in addition to "Light weight." To satisfy both the "Slim" and "Large size", "Flexible" function is required as macro dynamic function. These cannot be achieved by the extension of conventional silicon electronics, and the adoption of new device technology and new process technology is predicted to be essential.
Once the "Flexible" device is realized, new applications not even imagined today can be opened up. The meaning of "Flexibility" here includes "Expandable and Compressible", "Bendable", "Rollable", and "Foldable." The application can cover a wide range including expandable and compressible artificial skin for robots, sensors attachable to curved surfaces, roll-able large size solar battery, fold-able display, and the devices that can fit large size, curved or complicated shape objects.

The direction pursued by the new electronics featuring "Flexible, Large Size, Light Weight, and Slim" is different from that of conventional silicon electronics that pursues higher degree of integration and foster operation speed.
The new electronics aims at creation of new values. Although there are some accumulation of academic knowledge and elemental technology that support new electronics, it is not systematically arranged as one technological field. Along with the enhancement of academic base, close connection between the materials, process, device, and applied system is important.
To construct the basic technology for the creation of this new electronics, following R&D themes are proposed:

■ Research on basic physical chemistry of "Flexible" material
■ New process technology development and construction of process science
■ Design and evaluation technology development

This strategic program is a revised edition of ‘"Flexible" Electronics Base Technology R&D’ issued in August 2006, of which scope has been enlarged and reviewed reflecting the rapid progress in Japan and other countries.

## 67. Element Strategy【Executive summary in English】

The "Element Strategy" is a new strategy for constructing the base for the new materials science focusing on the "Element" based on the "Science", and is composed of following four strategies.

(1) "Reduction Strategy" that reduces the amount of use of rare elements and harmful elements to the utmost limit.
(2) "Substitution Strategy" that substitutes the function of rare elements by abundant harmless elements.
(3) "Recycling Strategy" that promotes cyclic use and reproduction of rare elements.
(4) "Regulatory Strategy" that pursues the innovation by clearing regulatory obstacles and making good use of these "reduction", "substituion", and "recycling"

The purpose of the Element Strategy is to realize various functions from various novel materials designed by deeply scientific understanding of the functions of elements under control of the concept described above without depending on particular elements. This strategy is effective as the generic policy for resourceless Japan and also plays the central role of the R&D relating to the design and exploration of the new materials and functions.

The term "Element Strategy", in general, probably means the political settlement of resource issues; for instance, by securing natural resources. This proposal provides an R&D strategy originated from Japan as one of quite effective scientific solutions against the global resources and environmental problems on the basis of materials science and technology that Japan proud of to the rest of the world. In orde to achieve these goals of the problem, it should be promoted in a large framework involving the inter-ministry collaboration and the participation of private sectors.

In the "Element Strategy" R&D, it is necessary to find a new approach for designing and exploring new materials scientifically instead of the conventional "trial and error" approach. In addition to the scientific knowledge based on the property of elements which give the basis for materials design, the scientific findings of cutting-edge nanotechnology, computing science, materials informatics and high throughput combinatorial technology we also useful for promoting the program, which will produce a new approach for materials R&D.

## 68. Strategic R&D project for control of nanostructuted materials to promote energy security【Executive summary in English】

Japan uses fossil fuel as major primary energy source, which occupies no less than ~80% of the total energy consumption at present. The renewable energies including solar remain as small as ~6%, and it likely takes a considerable amount of time until the energies become the main energy source. Although the nuclear power occupies ~13% of the total, it is practically impossible to supply the entire primary energy because of difficulty in finding locations suitable for nuclear plants. Therefore, it is generally recognized that we continue to utilize the fossil fuel for short and mid term, while making maximum utilization of the renewable energies and safety operation of the nuclear power. Under these circumstances, the first priority is to develop innovative energy conversion technology for the minimum consumption of hydrocarbon materials to ensure the energy security of Japan.

This R&D proposal provides “the co-production type energy and material production system”, in which energy conversion and material production with high efficiencies are realized using hydrocarbon as a raw material. The execution of the project through cooperative efforts between industrial and academic sectors in saving the energy and resource allows for managing the energy security issues of Japan by minimizing the energy resource acquisition battle and preventing the global warming as well. The system may utilize, as raw materials, a variety of hydrocarbons such as low grade coal, heavy residuum oil, organic wastes including plastic waste and garbage, and biomass, that is, the system may flexibly use wide range of raw materials from fossil to recycled resources, giving high additional value to low grade or minus valued feeds, which would require cost in case of disposal, garbage for example. The system co-produces electricity, fuel oil, fuel gasses whose principal ingredients are hydrogen, chemical raw materials mainly composed of C1 and C2 chemicals, and olefins. The ratio of these products (product mix) is controllable depending on the demand, resulting in providing substitutability and interchangeability in the energy resources. This may lead to the establishment of an optimized and robust energy system, in which the energy resources are ensured domestically.

## 69. Foundation of Common-Use Nano-Tech Integration Center directing to Financial Independence【Executive summary in English】

Inter-disciplinary integration of different fields and inter-sector cooperation among the industries, universities, and the government are indispensable for the creation of innovation. Especially, since the nanotechnology laterally relates to all the industrial fields, the research area can be drastically broaden by efficient execution of the interdisciplinary and inter-business integration, eventually opening up new-frontier. In other words, for the creation of innovation, it is the pressing issue to set up a concrete system that accelerates integration and cooperation by attracting many researchers from different fields for real success, since it is not sufficient to prepare the public investment for individual R&D project.

Therefore, we propose the foundation of "Common-Use Nano-Tech Integration Center" with nation-wide network which directs to financial independence. The "Independence Oriented Common-Use Nano-Tech Integration Center" is a common-use facility that meets all of the three requirements as follows:

[1] A common-use facility that aggregates cutting-edge equipments, realizing a whole necessary process of processing, measurement, fabrication, and manufacturing
[2] An open common-use facility (impartially opened for public) for preferentially supporting inter-disciplinary research; R&D by industry-academia-government cooperation; and promotion of human resource exchange
[3] A common-use facility that aims at independent continuous management through the combination of national budget (base), contribution of recipient organization (universities and national labs, etc.), the matching fund from local government, contribution from enterprises, and the usage fee

For the rest of the world, in their national projects on the nanotechnology, this type of common-use facility is established and managed strategically. For example in the U.S., South Korea, and Taiwan, 15 to 20% of whole nanotechnology R&D budget is allocated to the maintenance of infrastructure such as common-use facilities encouraging the promotion of inter-disciplinary research and the expansion of research front. On the other hand in Japan, although the significance of constructing this type of infrastructure is insisted in the 3rd Science Technology Basic Plan, however, no more than 2 to 3% of whole nano-tech and material budget (nanotechnology comprehensive support project:

FY2002-2006) is allocated. This proposal includes the construction of independence-oriented management system of common-use facility as well as the improvement of significance and substantial enhancement of this type of nano-tech integration center in terms of whole nano-tech and material R&D project from the mid-long term strategic point of view.

The purpose of this strategic proposal includes: (1) Highly-effective and productive support for the research activity by the aggregation of nanotechnology cutting-edge facilities; (2) Expansion of research front for the nanotechnology related industries and researchers; and (3) Acceleration of inter-disciplinary research as well as inter-sector cooperation among the industries and universities, and government. The center is supposed to provide a common-use infrastructure for the solution of social issues and a new system for the promotion of R&D, which aims at a management function capable of servicing mid-long term continuously.

## 70. Nano synthesis - Creative Manufacturing -【Executive summary in English】

The achievement of nanotechnology R&D will be returned to the society in the form of nanodevices or nanosystems such as data processing device, recording device, communication device, energy device, and sensors. Any of these nanodevices and nanosystems are important for the industry in Japan in the future.

To create these nanodevices and nanosystems, "synthesis-type" R&D is required. In synthesis-type R&D, a targeted nanodevice or nanosystem is created by integrating or fusing multidisciplinary technology and knowledge in the following way: 1) The new nanodevice or nanosystem is proposed based on existing or potential social needs and industrial technology trend, 2) The conception is broken down into technological elements to be studied or developed, 3) The technological elements are demonstrated by the prototype of the targeted nanodevice or nanosystem and concurrently-performed application-oriented basic research. In addition, the efficient manufacturing technology for the nanodevices and nanosystems must be developed, because the present nanomanufacturing technology is fragmentary and immature. Otherwise, the developed nanodevice and nanosystem cannot attain the final phase of commercialization even if the R&D is advanced.

Then, in this strategic program, we propose the following two types of R&D.

1. Synthesis type R&D which creates the prototype of new nanodevices and nanosystems
2. Technology development for efficiently manufacturing the nanodevices and nanosystems in industrially-feasible form and scale

The examples of the potential targets for Type 1 R&D are shown as follows:

1) Information & communication device/system: high-performance system LSI integrating RF components, optical components and other MEMS, proof-of-concept quantum computing devices, optoelectro devices integrating photonic nanostructures and advanced electronic circuits, etc.

2) Bio and mechanical device/system: self-controlled and self-powered sensor with wireless communication function, high-throughput DNA sequencing system for low-priced personal DNA analysis, advanced nanotool for scientific researches, etc.

Type 2 R&D aims to produce manufacturing technology which is possible to scale up for the commercialization of the nanodevices and nanosystems, of which examples are shown as follows:
Integration of top-down and bottom-up processing technology, the manufacturing technology for 3D or other novel CMOS, low-temperature processing technology to integrate bio and mechanical devices with advanced integrated circuits, the replacement of poisonous substances and rare materials by nanomaterials or nanostructures, etc.

For promoting R&D projects efficiently, this strategy also makes following proposals: 1) the construction of funding and evaluation systems suitable for synthesis-type R&D~~;~~ and 2) sustainable operation method of R&D infrastructures such as R&D center and common facility.

## 71. Wisdom Computing – Research and development for creative collaboration between humans and machines【Executive summary in English】

"Wisdom Computing" is our initiative to make our intelligent world richer and lead us to better decisions under our complicate and ever changing situations. We believe this initiative makes our human life better in quality and we gain abilities to deal with machines whose ever-increasing capabilities threaten human works and intelligence. We pursue this initiative by utilizing Information Science with collaboration of other disciplines such as social sciences and humanities.

Modern society is suffering from abundant knowledge and information, and we face difficulties to utilize this to make our life better in practice. The amount of information has been awfully increasing ever. However, they are unorganized, unstructured, and a jumble of wheat and tares. In this situation, we however have only a limited capability of search, extraction, accumulation, propagation and utilization of knowledge.

With continuous and exponential growth of computing power and storage capacity in the last fifty years, machines begin to show a substantial presence in our daily and work life. Artificial intelligence is now opening up a new frontier after decades of disillusionment. For example, in Shogi, the Japanese chess, nowadays machines compete with professional players; a computer defeated human champions in a famous quiz show in 2011. Advanced voice recognition and natural language processing technology enable us to enjoy voice search and foreign language translation at a practical level.

We, Center for Research and Development Strategy(CRDS) of Japan Science and Technology Agency(JST), assembled the survey titled “Panoramic View of the Electronics, Information and Communication Field(2013)” in 2013, and through this work we proposed to our government “Wisdom Computing” as a strategic challenge for the advance of our nation in this field. We shaped this concept by holding “Wisdom Computing Summit 2013” in July, 2013 and three follow on workshops focusing on wisdom computing and media, interaction, and communities. Through discussions among many multidisciplinary experts and researchers participated, we clarified the R&D orientation and the profound arguments on concrete R&D themes in this new academic discipline "Wisdom Computing".

"Wisdom Computing" aims to promote accumulation and propagation of wisdom, to accelerate scientific discoveries and to create a framework for better human lives. Considering the implementation of R&D to society, we focus on the following three viewpoints such as (1) the pursuit of what humans cannot do, (2) the pursuit of what existing sciences cannon solve, and (3) social-application conscious R&D.

(1) Accumulation, propagation and exploration of accelerating knowledge (the pursuit of what humans cannot do): Human cannot instantly make the most appropriate proposal by using a diversity of intelligence and knowledge connected to a worldwide network. In this proposal, we focus especially on the R&D of the interactions between humans and machines for accumulation, propagation and exploration of wisdom.
(2) Promotion of prediction and discovery ( the pursuit of what existing sciences cannot solve): Science has been a powerful tool to explain physical phenomena by applying scientific laws found through scientific observation. However, there still remain too complex issues for the known scientific laws to solve, and too complex scientific laws to describe by themselves. We pursue the R&D to accelerate scientific discoveries by using information science and technology as a lens or a computational way of thinking, like we use a telescope and a microscope to obtain completely new scientific views of the world.
(3) Actuation of knowledge into society (social-application conscious R&D): These R&D should contribute to better human lives including more persuasive decision-makings and effective social system operations. We pursue the new ways for the creation and circulation of wisdom by giving the actuation feedback to all the related scientists and actors.

To implement these R&D into society, it is important to construct a common platform which can be used and shared between intra- and inter-projects. Throughout the whole period, it is necessary to carry out R&D for ELSI(Ethical, Legal and Social Issues), which includes both positive and negative impacts of new science and technology. We expect research in ELSI and SSH(Social Science and Humanities) enables us to deal with situations where machines and computation far exceed human capabilities and human being need to devise a way to utilize their capacity for the sake of our happiness without threatening our dignity.

"Wisdom Computing" contains wide range of research areas with many challenges. Another issue is that the problems and issues which "Wisdom Computing" can address are broad and it is hard to produce results for society in timely manner without sound roadmap and focus. The targeting area varies from the simple and primitive levels for individuals or small groups of people, up to complex and high level ones for communities or social systems. Handling this type of R&D in an incremental and iterative approach is effective. In this proposal, the first step of "Wisdom Computing", we identified the following R&D agenda in order to solve the simple and primitive issues for individuals or small groups of people.

1. Research agenda for defining and clarifying problems to solve by interactions between humans and systems
   1-1 Reducing ambiguity of the issue by interactions between humans and the system
   1-2 Understanding human behavior, intention or situation
   1-3 Decomposition and transforming of the defined problems

2. Research agenda for constructing knowledge bases
   2-1 Acquiring, representing and accumulating knowledge
   2-2 Semantic representing and processing
   2-3 Constructing, managing, and maintaining knowledge platform

3. Research agenda for answering, suggesting, advising, or arguing capabilities
   3-1 Inference, hypothesis generation or simulation technologies for prediction
   3-2 Community building for collaboration among humans and machines
   3-3 Technologies for presentation options, explanation or persuasion

Social and economic impact of "Wisdom Computing" is that social implementation of R&D accelerates accumulation, propagation and exploration of knowledge. We accumulate and interlink abundant data, information and knowledge. Propagation and circulation are promoted to enable us to explore and use desired data in a natural manner. Newly obtained knowledge is stored and reused for later use throughout the entire society. Thus, we will be moving a step closer to the realization in a highly intelligent society, where the quality of our decision-making is improved and persuasive solutions to previously unsolvable issues are acquired, by synthetically analyzing evidences from different systems, and gathering wisdom from a diversity of humanity.

As scientific impacts, the first is to create a new research field "Wisdom Computing". The goal is to become a multidisciplinary field composed of not only natural sciences such as artificial intelligence, cognitive science, brain science and robotics but also humanities and social sciences such as economics and psychology. The second is to establish new relationship between humans and machines not by treating machines with incredible power as a threat or only as a tool, but by fostering machines to conduct intelligent information processing to support humans as partners.

To create a new academic wave "Wisdom Computing", the R&D should be continued over at least 10 years. Therefore, it is important to provide consecutive funding, to establish a research community both domestically and internationally, to be recognized the value by industry and society, and to maintain academic activities internationally. We also make efforts to stimulate researchers' challenges and to cultivate young researchers. CRDS will positively and continuously engage in these activities.

In the process of making this proposal, a part of the concept of "Wisdom Computing" was reflected in one of the 2014 Strategic Objectives of Japan "Development of Intelligent Information Processing Technology to Realize Creative Collaboration between Human and Machines". Then, JST initiated a new Research Area of CREST "Intelligent Information Processing Systems Creating Co-Experience Knowledge and Wisdom with Human-Machine Harmonious Collaboration". We hope that researchers who apply for and participate in the CREST comprehend the grand design of "Wisdom Computing" and understand the position of the CREST in it.

## 72. Transdisciplinary Platform for Risk Knowledge (TPRK) and Its Deployment Strategies - Towards Structuralization of Common Knowledge in the Risk Society -【Executive summary in English】

This proposal addresses the development of an interdisciplinary common format for the potential and combined risks that might have a serious impact on society; in general, we call them “systemic risks.” The proposal also discusses a knowledge platform and its management system for the integration of the knowledge of risk.

Currently, people are exposed to various risks, including natural disasters, accidents, pandemics, financial crisis, and cyber attacks. For each individual risk, the possibility, reason for the incident, impact induced, and the measures for prevention thereof are studied in each specific field. Actually, however, the situations where the measures become one step behind, despite the various disasters that occur frequently, are repeated. In the 4th Science and Technology Basic Plan in FY 2011, they pointed out the flaws inherent in the risk management and crisis management in Japan. Neverheless, compared with major foreign countries, there are no unified organizations to manage and control systemic risks hard to prior investigations in Japan.

Mutual connections and causal relationships exist among various risks. If we successfully extract underlying common structures from them and establish general methodologies for dealing with risks, we are also able to deal with potential risks by using such general methodologies. For this purpose, it is necessary to grasp each specific risk study as a system component and to understand the overall structure of combined individual risks as a total system. As a start point, technical terms used in risk studies must be commonly unified, integrated risk khowledge bases are developed, then a risk management institution must be established.

The concept of risk is defined, in general, by the combination of the likelihood of occurrence and its negative effect. Regarding the systemic risk that has a significant impact on socio-economic systems, it is difficult to accurately estimate the likelihood and to fairly evaluate the negative effects due to the human cognitive bias. This point gives rise to obstacles in dealing with risks. In addition, since it is not possible to see through the systemic risk with an independent single principle, measures will be required where complicated interactions among various fields are taken into consideration.

On the other hand, Japanese academic societies have accumulated a vast number of risk studies, including the environment, medical care, finance, and networking. However, owing to the different meanings of the major concepts in each field, the outcomes in those studies have not been utilized in an effective way. We must build a system, which 1) puts the risk concepts in each field in a common way, 2) deals with the practical risks in a society, and 3) translates data and knowledge among the fields. Furthermore, we also must disseminate the products of the latest studies in reliability engineering, risk sciences, and resilience engineering to the other research fields.

Therefore, the problems to be solved in recent research and development on risks are summarized in the following three items:

1) Individual risk studies are isolated and have no relationship to each other;
2) Risk studies require new methodologies to analyze potential or implicit risks;
3) A total support scheme must be established to collect, maintain, and manage the information on systemic risks.

Regarding Item 1), the information systems usable by experts in the respective fields are required; regarding Item 2), a platform for transdisciplinary studies are required; and regarding Item 3), an integrative risk management organization is required.

We propose in this report “Transdisciplinary Platform for Risk Knowledge; TPRK” shown in Figure 1. The development of TPRK requires the following three phases. Phase 1: Build the platform as a total information system; phase 2: Store and link together the results of each research field; and phase 3: Keep TPRK operational and manageable for a long time. In addition, an authorized organization must manage the risk concepts and analyze the scenarios regarding the potential and combined risks on the platform. For details of the above-stated three phases on the TPRK development, refer to the progress report CRDS-FY2013-XR-03.

The social effects of the use of TPRK will include the following five points:

1) Identification of relationships of potential and combined risks in the preparation of science and technology policy related to risk management and crisis management, as well as scenario analysis for preventing the expansion of risk;
2) Measurement of transdisciplinary risks and prediction of the range of propagation of risk events;
3) Support for risk assessment activities based on scientific evidences in each field and

the provision of risk information;

4) Dissemination of literacy related to potential and combined risks among citizens; and

5) Establishment of risk management policies in Japan by the risk management organization.

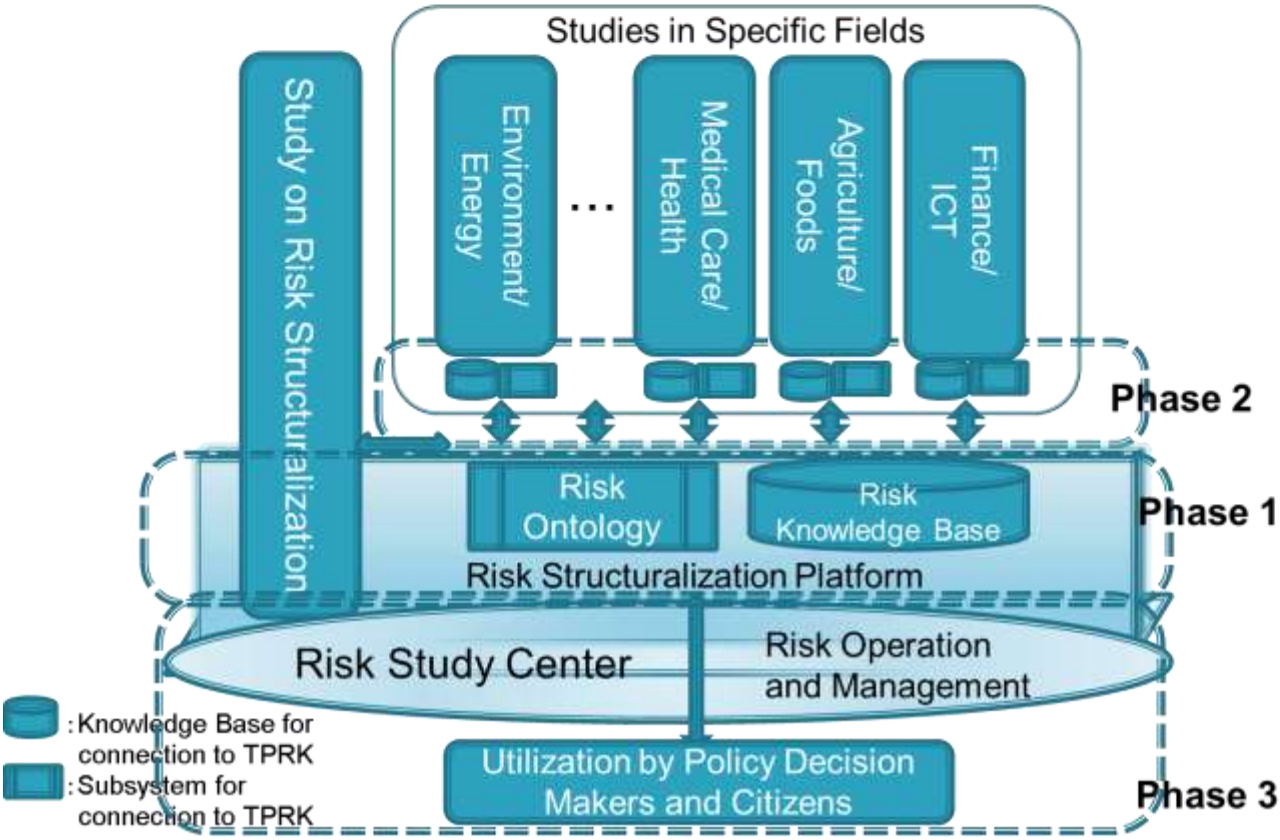



Figure 1　TPRK Configuration and Operation Concept

## 73. Research and development on fundamental technologies of cyber physical systems and their social implementation -A case study on promoting aged people to social activities【Executive summary in English】

CPS (Cyber Physical Systems) has wide variety of meanings such as tiny embedded systems, automobile systems and nationwide electric power networks. In this proposal, we define CPS as a system which includes not just computational and physical aspects, but also human. CPS gathers, processes and utilizes data from real world and human. It contributes to make every social system more efficient. Moreover it can help create new business. There are 2 issues for CPS to be accepted as a social system. The first one is as follows. There should be well defined common basic technologies to improve development efficiency, to realize integration of different CPS and to expand application services. The second issue is to pay much attention to its design, development and operation in conjunction with stakeholders, rather than just focusing on IT since CPS is tightly connected with the social activities.

Here we propose to challenge these issues by using a case study of promoting aged people to social activities. It is very important for Japan to help aged people join social activities lively, because we can obtain labors and they improve their QoL. Hence, the society can save cost of medical and welfare.

To promote aged people to social activities, we propose CPS technology which divides social activity into sub activities, then it assigns each sub activity to those who can accomplish it. CPS will overcome inconsistency of time, space or skill. Thus people can join social activities through cooperation and collaboration with others. We would like to promote aged people to social activities and finally we hope to contribute to create new business by realizing CPS.

R&D targets are

1. Information architecture to realize service integration and physical world modeling.
2. Systems architecture to support developing various types of social CPS.
3. Assuring CPS reliability as social infrastructure including countermeasure of cyber-attacks.

It will take long time for social system to be effective. Sometimes, at the begging it cannot be economical. Therefore, we need stable and long term support from government. On the other hand, R&D plan should be flexible depending on technologies and circumstances. We propose to build R&D system which has natural selection mechanism.

## 74. Research on integrated modeling system toward solving future water problems - Implementation of strategic research on building systems – 【Executive summary in English】

To build a sustainable water circulation system, we should promote effective use of water resources, restraint of environmental burden, and conservation of energy and resources more than ever. After integrating three concepts related to water—flood control, irrigation, and environment—which had been developed separately for historical and other reasons, we need to understand the water circulation system comprehensively, and optimize, manage, and operate it to solve the issues. Under the present circumstances, however, we cannot easily achieve this, due to restrictions on technology, cost, human resources, and systems.

One of the crucial technical barriers is the lack of an integrated modeling system, which represents the entire complex and large-scale regional water circulation system intertwined spatially and temporally and is used for various simulations.

Models related to the water circulation system consist of artifact models such as dams, water treatment facilities, and conduits; natural environment models such as rivers, lakes, and groundwater; water utilization models such as water for various purposes; social and economic models, and so on. These models have been studied and developed independently by specialists in respective fields. Because complex problems related to water circulation cannot be easily solved by a single model, collaboration among multiple different models is required. However, the research to serve as the foundation of the collaboration and integration has almost never been conducted. Without the integrated modeling system that enables collaboration among various models, it is difficult to precisely visualize the entire image of the regional water circulation system we are aiming to build. Without quantitative and qualitative evaluation data, a proper judgment cannot be made when presenting the vision of a new smart city in developing countries or when optimizing water supply and sewerage facilities in a certain river basin in Japan by integrating the existing water infrastructure.

Without being researched and developed based on the actual targets, the integrated modeling system cannot go beyond the scope of academic interest to be implemented in society. It cannot be deepened without active contact with actual technology. Therefore, we propose selecting some regions at home and abroad and target systems to be implemented, and organizing a research team in each region. We will promote research and development aiming to solve specific issues by working in a team optimized for the different situations of the respective regions.

More advanced technical barriers include the lack of the viewpoint to see the regional water circulation system as a part of the comprehensive system including social and economic environment, and the immaturity of the systems science and technology to support system building. Also, more advanced “barriers to system building” do not apply only to a water circulation system. We face similar issues in most attempts to implement technology extensively in society, such as social infrastructure for energy or other resources. Unfortunately, a scientific method to overcome these issues is yet to be established, and engineers’ skill has not been developed sufficiently to solve them. Moreover, in the actual development stage, even for an artificial system that can be handled as a relatively closed one, most of the designing and building process relies on engineering methodologies such as enterprises’ manuals or engineers’ expertise, and has not yet been systematized scientifically. If the scale, complexity, and time range of the system expand to the level of the regional water circulation system we are attempting to handle here, it will be impossible to cope with it only by the conventional engineering approach.

To work on building the regional water circulation system, we should not see it at the same level as designing and development of an artificial water treatment plant. Instead, we should see it as system building at a higher level, including nature and social and economic environment. With this perspective, we think that we can exceed the limit of the research and development conducted from the viewpoint specific to water issues, thus achieving new results for social implementation of the system.

The strategic research for building systems, which has been proposed by the CRDS up to now, is a procedure on what to consider and how to proceed with building in the planning, executing, and implementing stages in the research and development project of the target system. With the knowledge accumulated by conducting the project according to the procedure, we also aim to deepen the system building methodology, which is still based on an engineering approach and not systematized scientifically, and develop a part of it as a new academic field.

Furthermore, this document also proposes a new research system structure and promotion measure, which is to divide the research team into a group leading the strategic research for building systems, a platform group for implementing the integrated modeling system as software and a water specialist group in charge of the development of water-related models. The three groups will organize heterogeneous research teams, and active interaction between the groups will lead to the social implementation of water systems.

## 75. Transdisciplinary research on integration of infrastructures for urban service system 【Executive summary in English】

The government makes policies using scientific knowledge in a broad range of fields. Science can provide an important basis for ensuring the validity and reliability of decision making. In the 21st century, as the relationships of science and technology to society and economics are greatly increasing their complexity and uncertainty, the role to be played by science in the process of policy making will continue to grow.

Recently, efforts to ensure the validity and reliability of science-based policy making have been made overseas. In the United States, while rules concerning the process of scientific advice have long existed, the Obama administration is accelerating the effort to ensure scientific integrity in the government. In Great Britain, various principles regarding science in policy making have been established since the BSE crisis in the 1990s. In many other advanced nations as well as international organizations such as the European Union (EU) and Inter Academy Council (IAC), similar efforts have been made.

In Japan, the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Station accident in March 2011 have prompted the examination on the roles and responsibilities of science and government in policy making. The 4th Science and Technology Basic Plan, adopted by the cabinet in August 2011, specifically mentioned the need to examine the relationships between science and technology and policy and to establish basic principles on this issue This proposal presents draft principles on the roles and responsibilities of science and government in policy making. This draft is intended as a starting point for discussion among a wide range of stakeholders to raise awareness of the importance of this issue and refine the rules on science-based policy making. Through such discussion, the government should establish the principles, and relevant organizations should then consider drafting their own guidelines. The draft principles in this proposal consist of the following items.

(1) The role of scientific advice in policy making
(2) Seeking scientific advice in a timely and pertinent manner
(3) Ensuring the independence of scientific advisors
(4) Awareness of responsibility as scientific advisors
(5) Achieving broad perspectives and balance
(6) Ensuring the quality of advice and integrating opinions

(7) Proper handling of uncertainty and diversity
(8) Free disclosure of scientific knowledge
(9) Even-handed treatment of scientific advice by the government
(10) Ensuring transparency of the scientific advice process

This proposal also presents measures necessary for laying foundations for science-based policy making. For example, efforts to create mechanisms for scientific advice in emergencies, ensure the enforcement of the principles and guidelines, and foster education concerning the relationships of science and technology to policy and society are necessary. Through such efforts, along with organizational reforms now being considered by the government, the effectiveness and integrity of science-based policy making in Japan should be secured.

## 76. Promotion of information science & technology research focusing on information structure of system including human【Executive summary in English】

This strategic initiative proposes to promote new research for information science and technology focusing on information structure of systems which include human factors.

On the site of social activities, a diversity of information is generated, distributed, accumulated and re-generated. There is no site that works without information. By perceiving a site as a system, humans, which are one of the formation in the system, gather information from their surroundings, process it and transmit it as new information. In a system where more than one person is involved, information transmitted from one person is received by another, and processed there as new information when it is retransmitted. This kind of sequential information flow or relationship can be regarded as a“ structure”, which we will refer to as an“ information structure” in this strategic initiative.

By analyzing the information structure of systems which include human factors, we will promote the research for information science and technology to construct a system in various application areas which will (1) predict the uncertainty and complexity increased by including the human formation element; (2) enable its easy control, and (3) optimally amplify human activities. Furthermore, we intend to extract the common elements and systemize them in the future. In the past R & D projects for information science and technology which included the human factor in the system, certain results have been achieved. The achievement, however, has been mainly in the development of individual technology regarding the interface of humans and ICT systems. Taking this into consideration we propose the promotion of research for information science and technology aiming at the systemization from the viewpoint of information structure of systems which include human factors.

Japan has an accumulation of ubiquitous technologies such as electronic components of excellent quality, material or nano-technology, embedded system technology and sensor technology. In recent years, cloud computing technology has seen rapid progress, enabling the process of enormous amounts of data. With the technical developments of such sensors and cloud technology, it now seems feasible enough to apply research methods or ICT unthinkable of at least 5 years ago, not only from the viewpoint of performance or functions, but also the cost affordability. For example, it has now become possible to distribute sensors to fields related to humans or human activities and make explicit knowledge about the tacit knowledge buried in the enormous amount of stream data. Various phenomena related to human behavior has been difficult to handle scientifically up till now, but being backed by the analysis of the enormous amount of data, it now seems possible. It can be said that the time has come to start the research for information science and technology focusing on the information structure of systems which include human factors.

Owing to the progress of research for information science and technology focusing on the information structure of systems which includes human factors, the best mix of role-sharing and value co-creation between ICT (which amplifies human activities) and humans will be promoted. The fundamental technology which enables the effective improvement of quality by adopting ICT in various social activities (such as administration, industry, education, public service) is created. By constructing an information communication system based on fundamental technology such as this, it will contribute greatly in improving industrial competitiveness in every industry in Japan. Also, from the viewpoint of value co-creation of embedded system technology at which Japan is strong and humans, there is a possibility to create an area of research and industrial domain of which Japan could take the lead. Furthermore, we can contribute to the construction of a robust information and communication system against disasters such as the recent Great East Japan Earthquake. It is also expected to contribute in solving problems during disasters in such cases where information credibility or accessibility, which are the negative sides of amplification, may become issues. By continuing the string of research regarding the information construction of systems which include human factors, we will be able to generalize it as a theory and academically systemize it, thus developing the theory to other applicable fields.

## 77. Towards solving important social issues by system-building through systems science and technology【Executive summary in English】

Enjoying the benefits of science and technology through a variety of systems is a characteristic of the present “age of systems”. The system is a complex which connects appropriate elements to realize purposefull functions. The recent systems tend to be more complex and larger scale than ever. Thus, the science and technology related to the system, in other words, “systems science and technology” plays an important role as the academic science necessary to analyze, design and implement the system. However, systems science and technology has never been the subject of a full-scale government promotion measure in Japan, but almost a “neglected science and technology”. How and why it became so is analyzed in detail in the interim report, “The Role of Systems Science and Its Issues in Japan” (CRDS-FY2010-XR-07), which we made in the process of preparing this recommendation.

Systems science and technology basically has a different character from science and technology in conventional fields in several aspects, thus its promotion measure is inevitably different from other sciences and technology. The first feature is that systems science and technology seeks the logic universality of the artifacts by eliminating the individuality of the fields. Therefore, its results are expressed as abstract theories or theoretic approaches, different from the results of conventional science and technology where one would be able to see or touch something in the case of the discovery of a new substance or completion of a device. As a matter of fact, the system itself cannot be seen or touched, making its results even more the same. The second feature is that since systems science and technology originally seeks to integrate the elements with various functions into one general function, it is often placed in a phase which connects basic and applied research, where its ability can be fully extended. The third feature is that systems science and technology research is constantly connected to building the actual project. It is important that it is tempered by producing effective results in such circumstances. In such cases, one must recognize that, from the universal characteristic of systems science and technology, there may well be a synergetic or ripple effect. Thus it is important to build a research organization which could adequately soak up such results.

This recommendation proposes the promotion measures for systems science and technology in order to solve the present issues that it faces, taking its features previously mentioned into consideration. Most important of all is to extract the necessity to build a system required to solve socially anticipated high-priority issues and specify it. Of course not all priority issues need to build a system, but in many cases, building appropriate systems become the final solution. For such issues and projects, to keep a right perspective from the view point of building systems, to extract and structure the necessary element researches from that perspective, and to guarantee the purposiveness of the element researches, are desired. This cannot be achieved by trendy planning abilities or management by objectives. We need cutting edge research. For this purpose, we propose a new research category called "*Strategic Research for Building Systems*" in this recommendation. "Strategic Research for Building Systems" would specify the measures to integrate the related individual themes as a system, and take the leadership in the entire research which would streamline the necessary decision making. "Strategic Research for Building Systems" would not only take the leadership in the planning stages, but also in the actual implementation process of the research in order to adjust and advance the purpose according to environmental changes. Up till now, in the top-down government projects, it has been impossible to make drastic changes in a plan once it is started. The lack of flexibility in the project implementation has often been pointed out. However, "Strategic Research for Building Systems" would be able to compensate for such drawbacks and secure the timely evolution of the project.

Proposing "Strategic Research for Building Systems" would be a promotion measure taking into account its academic character of systems science and technology, in other words, it is a science and technology combined with both basic and applied research, intrinsically aiming at the solution of issues. At the same time, "Strategic Research for Building Systems" would not only temper systems science and technology as an issue-solving type of science and technology, but also advance the fundamental research of systems science.

To be more concrete, we intend to implement "Strategic Research for Building Systems" immediately to those whose missions are to build systems among the projects which are scheduled to be conducted under the new growth strategy, and validate its effectiveness. Along the same line, we will pick up issues which we face where the system construction is a key factor, and fully implement the "Strategic Research for Building Systems". As examples of such issues, we propose three projects. As we have already mentioned, the abstraction and universality of systems science and technology will bring synergetic or ripple effects to the results. In order to soak up such synergetic or ripple effects, it is necessary to have a central organization to conduct and integrate systems science and technology in the process of promotion of systems science and technology.

By making systems science and technology have a strong presence in the science and researcher communities in Japan, the rapid transition of science and technology policy from field specific to problem-solving types is anticipated. Also, by formulating the issues which specify the intentions of building systems, we could structure element researches and streamline funding. In order to implement science and technology in today's complicated society, it is necessary to build a system open to society, not one that is closed in its own local technical world. Thus we need to stand on a solid research base of human mentality and behavior. Therefore, "Strategic Research for Building Systems" requires cooperation from the fields of social science and humanities. Systems science and technology also holds research areas adjacent to social sciences such as business administration, economics, modeling, and social simulation, which implies that it will play the role of catalyst by further increasing the present integration of humanities and sciences.

"The Limits to Growth" commissioned by the Club of Rome in 1972 gave a revitalizing role to systems science and technology. There are many large organizations for the research of systems science and technology in the world. Among them, China is active in the research of systems science and technology, and the Chinese Academy of Sciences has a large research organization for the field. In Japan, there are presently no research organizations which focus on systems science and technology, let alone the existence of such research organizations in any university or government institution. With this recommendation, we plan to improve the level of systems science and technology, and hope to become a model country for solving problems as referred to in the new growth strategy.

## 78. Software technologies for adapting requirement changes of information systems【Executive summary in English】

Today information systems are the basis of almost all of the infrastructure of our society. Any failure in the information systems will cause tremendous impact on our society. Society requires information systems which are safe, secure and stable. It is widely recognized that the major cause of the information system failures is in software, which is steadily growing larger and getting more complex.

Research and development on software technology for safe, secure and stable information systems has been carried out for many years, and software development tools and methodologies have been developed to improve productivity and reliability. Although it seems as if software technology is approaching a maturity level, software in information systems based on open networks still have problems. For example, it is difficult to adapt to 1) unpredictable needs of unspecified users, and 2) the inevitable environment changes such as aging degradation of the information system itself or user's specification changes. The issue of how software technology could cope with such changes in information systems is no longer solvable only by the patient efforts of individual vendor. In order to deal with the software issues which are getting massive and complicated, the major Japanese vendors recently established Dependable Software Forum (DSF)[5]. In academia, various methodologies and tools were developed as the result of basic research. However, the results were not widely applied in industry. Each methodology and tool alone, on which the academia has been working, can not cover the overall life cycle of information systems (design, development, operation, maintenance). Thus, the applied research to integrate multiple research results is of great significance. In order to achieve the goal of stable operation of the information systems which support the infrastructure of various industries, we should strongly pursue the industry-academia collaboration in basic research and applied research.

In this strategic program, we propose basic research on specific subjects, and strong industry-academia collaboration for applied research to integrate the results of basic research.

In the life cycle of an information system, which is its design, development, operation and maintenance, conventional researches have been mainly focusing on the design and

5 http://www.nttdata.co.jp/release/2009/122200.html

development phases, especially on improving the productivity and reliability of the software. However, in the future, software technology will be required capable of realizing a sustainable information system which can respond to the various environment changes including the changes in specifications during operation. Not just design and development phases, but research on holistic approach towards the entire life cycle should be pursued.

For the purpose of covering the entire life cycle, we propose basic research subjects such as extraction and analysis of the changing specifications, description of changes in models, program inspection, monitoring etc. Furthermore, in order to apply the results of such basic researches to real systems, we propose promotion of applied researches integrating multiple research results through industry-academia collaboration.

If all of this goes well, the expected outcome will be as follows: we can contribute to the world by showing methodologies and tools for implementing information systems that can cope with various changes and operate sustainably and stably. We will also be able to nurture researchers and engineers who have system thinking capability.

## 79. Building a system for the integration of multiple simulations -A Practice in earth system modeling research-【Executive summary in English】

There is a growing need to integrate multiple simulations (integrated simulation) in order to simulate complicated system's behavior. Earth system simulation is a typical example. If we want to simulate total behavior of the earth system, we need to integrate simulations of atmospheric circulation, oceanic circulation, aerosol diffusion, ecological system, traffic system, economic system and so on. Researchers in different fields, such as climatology, oceanography, geochemistry, etc. are developing simulation programs for their own research purposes. To understand and predict the behavior of the earth system, which is a quite complicated system involving all of such fields, it is necessary to integrate the simulation programs developed independently for different purposes. Only limited effort, however, has been so far made to make the integration possible.

From this point of view, this strategic program proposes:

1. Building a community of collaborative researchers who are willing to accept a certain level of restrictions in their simulation programs to make them interoperative, and
2. Developing infrastructure that allows the researchers' community to carry out integrated simulations without imposing an excessive burden on the researchers.

Taking advantage of achievements made through prior investment, freely accessed/ open environment for integration of multiple simulations is recommended to be constructed and research and development should be carried out going ahead of other countries.

In recent years, the problems of global environments get worse, as seen in global warming, environmental pollution, the exhaustion of resources, the reduction of biodiversity, and so forth. Concrete targets for mitigating the climate change have been set in international negotiation. It is urgent to tackle the problems so as to achieve the targets. In addition, it is sufficiently recognized that the creation of a social system adapted for the climate change is urgent. Policy decisions meeting such social needs have huge influences over the future.

In order to make decisions more reasonable and convincing, it is required to properly forecast future and also design countermeasures against the problems. The object of the forecast and the design is an "earth system" in which a variety of elements are interacted mutually. Accordingly, it is strongly required that the policy decisions are technologically supported by simulations. Pieces of knowledge have been accumulated in the disciplines of atmospheric circulation, oceanic circulation, aerosol diffusion, ecological system, traffic system, economic system, and so forth. On the other hand, the system for linking and using the pieces of knowledge is extremely insufficient.

It is difficult for researchers carrying out intellectual exploration to have an incentive for taking care of a technical consistency with other disciplines. That is why it difficult to link and use simulation programs each other. To overcome this difficulty, a new community should be built which has an incentive different from that of individual disciplines. The community will work to construct a system for the integration of multiple simulations. Community building is recommended to be promoted with an issue of "Creating a New Society Adapted for Climate Change". Driven by a strong social wish adapting for climate change, the government and the researchers collaborate to overcome this difficult issue.

The community should be formed by researchers interested in the integrated simulation from the academic disciplines such as climatology, oceanography, geochemistry, bionomics, social psychology, traffic engineering, economics, and so on in which their own simulation programs have been constructed for their own researches, and from the academic disciplines such as statistical mathematics, computer science, and so on which can provide scientific knowledge required to execute the integrated simulation. In the community, the whole image of a required simulation and technological specifications necessary for integrated simulations should be investigated, defined, and agreed.

A technological platform on which the integrated simulations are executable should be constructed based on the agreed technological specifications. On the technological platform, a number of simulation programs and databases will be connected via an information network, and a control program will be implemented. In addition, statistical mathematics technologies for optimizing a large-scale simulation program will be developed through a number of integrated simulations. The community members will build their own simulation programs and databases on the technological infrastructure, and will try to get new perspectives through the collaborations. Accordingly, the technological infrastructure should be continuously developed through the trial and error.

To continuously develop the technological infrastructure, a project head office, the core of the newly formed community, is recommended to be set up in a public research organization[6]. A program officer as a president for this project and a fund manager as a responsible person for fund-raising should be deployed in the head office. They will captain the project teams and provide research-fund. Engineers staffed in the project head office should support the construction and maintenance of a research infrastructure through close cooperation with the researchers from home and abroad.

Continuous fund-raising, dialogues and cooperation with the researches from home and abroad are necessary for the research and development of fundamental infrastructures. In the past, such efforts were made by researchers themselves. Reflecting on the facts, financially and technologically supported research environment should be provided to researchers under the leadership of program officer and fund manager. It makes the research project attractive and continuous.

As the technological platform is aiming at the platform for mutual connections, it should be common. The related technological trends of other countries should be studied, and the collaboration should be made appropriately. The project promotes that the technological platform becomes widely used and is recognized as a world standard. Japan should provide technological leaderships to solve the large-scale, complicated global problems. Researchers from abroad (including developing countries having no large-scale computational resources) are welcome to construct shared technological infrastructures.

It is very beneficial for the society that the results of research are opened for public and are accountable. The head office should ensure accountability for the results without imposing an excessive burden on individual researchers. Under the system, open mind-set of the researchers will be encouraged.

[6] This project head office should be taken as the essential activity of the nation, and budgeting for the head office should be continuously made. Accordingly, it is to be noted that the activity should be supported not by temporal budgeting but by continuous supporting form.

## 80. Integrated Research and Development for Wireless Communication Technologies Supporting Ubiquitous Information Society【Executive summary in English】

One of the key technologies for the ubiquitous information society, expected to come in near future, is wireless communication, and we propose, in this strategic program, to proceed the R&D activity on the basic technology of the wireless communication in a consistent manner from the communication method to the circuit, device, and materials.

In future, the arrival of "Ubiquitous Information Society" is expected, in which computer chips and sensors are incorporated in a variety of surrounding things and connected to the network, which will provide convenience, safety, and economy. As being free from locational restriction, a wireless communication system must be adopted in such network. Therefore, as a core technology for supporting the social infrastructure of the near future, the significance of the wireless communication technology is expected to be much higher in future.

In terms of the wireless communication technology, Japan is traditionally superior in hardware technology such as antenna propagation, micro waves, and millimeter-waves, and network encoding technique. In these days, Japan takes the lead, with prominent researchers and engineers, in the new research fields such as cooperative wireless communication system that connects multiple wireless communication nodes. Also in the material and device technology, there are many fields led by Japanese such as crystal devices. However, the R&D activities so far tend to be proceeded independently by the researchers in respective field, and the power of the whole Japan may not have been fully aggregated and demonstrated. In the United States and Europe, the research of new generation services and applications such as the cognitive wireless technology that uses unused frequencies dynamically, the wireless sensor network that considers power consumption, and the mobile terminal devices, is already started. In this strategic program, we propose to proceed a R&D from the system, circuit, device, to the materials in a consistent concept to raise the academic and industrial engineering levels in the field, construct the social infrastructure, strengthen the industrial competitiveness, and work on the human resource development.

The basic wireless communication technology includes such elemental technologies as modulation, encoding, encryption, authentication, and multiple accesses, which are deeply related to mathematics. Therefore, we propose a research of the system initiated by wireless communication researchers and mathematicians working together. This may result in creating new idea which would not be just an extension of the conventional system. Especially, the bandwidth available for the wireless communication is limited, which should be utilized as effectively as possible. From this viewpoint, the effective use of unused frequency band, spatial multiplexing technology such as micro/pico cells, and the dynamic allocation of frequencies are important, and we propose the R&D on these new communication methods.

In addition to the new system, the research on the circuit, devices, and materials for realizing the system is also important. More specifically, the R&D themes include the high frequency circuit, Digital/Analog conversion circuit, antenna, high frequency materials, and others. They include not only the hardware elements but also the software elements. Also for such software elements, we must cooperate with the researchers of the total system architecture to specify the requirement specification of the circuit, device, and materials. An effective and harmonized R&D can be made possible by providing the feedback of the state-of-the-art technology from the device and material level to the circuit level, and further to the system level.

## 81. Theories and Technologies for Supporting Knowledge Creation in Organizations【Executive summary in English】

After the eras of industrialization and informatization, the society is shifting toward the knowledge base society. In the knowledge base society, the "Knowledge" is highly valued rather than goods and information, and the production and utilization of valued knowledge is the resource for competitiveness. Under the study of the science technology for the knowledge base society, we have proposed to construct new science integrating the cultural science, information science, and cognitive science at the strategic initiative, "Challenge for Constructing Science for Producing and Utilizing Knowledge", in February 2008.

In this strategic program, we propose specific R&D themes and promotion method for the R&D in order to systematically construct the theory and technology on organization's knowledge creation support by focusing on producing new knowledge for the organization.

Specific R&D themes include observation and analysis, modeling and analysis, design and operation of site, supporting technology, and others. More specific examples are as follows: the observation and analysis - a behavior analysis of participants in a meeting using camera picture; the modeling - the modeling of knowledge sharing process or the modeling of the relationship between the individual model and organization model in the knowledge creation process; the site design - an office design stimulating creativeness; and supporting technology - the support of sensuous I/O, the support for enabling intuitive understanding and operation, the support for awareness, the support of metacognition verbalization, and the support for knowledge sharing by collaborative learning.

Assuming some of the sites, a research team, composing the researchers of information science, cognitive science, and business economics, is set up for each site to promote the R&D through the application of IT tools, methods, and theories. A steering team is also set up to examine assignments common to each team and to discuss systematization. Moreover, as a pre-step for executing full-fledged research programs, a workshop or feasibility study is executed to “educate” the researcher's communities.
By setting the knowledge creation in an organization – core activities in a knowledge base society – as a centripetal force, information engineering, statistical mathematical

science, business economics, psychology, cognitive science, pedagogy, and others are integrated to lead the construction of the knowledge science ahead of the rest of the world, and a theory scheme is originated from Japan to demonstrate the global leadership in this field and to contribute to the advancement of science.

Disciplines are not yet made clear for uniting the researchers in quest of the goal, "Constructing Science for Producing and Utilizing Knowledge", proposed in 2008 proposal. The only way to challenge the goal is to repeat the trials and errors for gathering the knowledge and will of the researchers who want to open up the unexplored field. This strategic program intends to provide the first step towards the goal.

## 82. Basic Technologies for Service Innovation Based on Mathematical and Information Science【Executive summary in English】

In this strategic program, the R&D of basic technology contributing to the efficiency improvement and advancement of services, especially in the aspects of mathematical science and information science, is proposed along with the specific R&D themes and the promotion method.

Since the concept of "Service Science" was mentioned in the report, "Innovate America", announced by the Council on Competitiveness in December, 2004, "Service Science" or "SSME (Service Science, Management and Engineering)" has become a hot topic and been studied in many countries. However, since the full picture of this field has not been made clear and there is a variety of definitions in "service", no consensus is reached yet. The relating discipline includes organization management, marketing tool, and business custom and ideas in addition to mathematical science, information science, cognitive science, psychology, and economics. Many people from different fields have been trying to examine whether such integration with a variety of elements can be systematically handled.

In this strategic program, we propose a continuous examination for the integration of various elements described above and an R&D focusing on mathematical science and information science that play a leading role in the field. As services significantly involve humane elements in the process, the degree of uncertainty, complexity, and transitory (non-reproducibility) is much higher than goods. Such a feature provides new R&D subjects for mathematical science and information science. To challenge these subjects, we propose to work on the following R&D.

- Technology for modeling complicated real services
- System optimization technology that allows specific uncertainty
- Technology for integrating raw data and for extracting knowledge
- Technology for analyzing the system with complicated causal structure to improve predictability of its behavior
- Integration of elemental technologies for the application to actual service

As a method for promoting these R&D, we propose the following approach. Public and influential service fields (e.g. medical service) are chosen, where service provider and the researchers of mathematical science and information science can work together. Projects are run in parallel and the results are integrated to generalize the theory and technology. An effort to integrate different technologies as above should be also maintained.

## 83. Promotion of Empirical Research on New Generation Network 【Executive summary in English】

The network industry is supporting the core national social infrastructure, therefore, it is very important for Japan, for the sake of industrial promotion and national security, to maintain advantageous standing in the international competition and continuous development. For that purpose, we must promote not only research and development of technologies but also training human resources who will have practical skills in mid-long term. In addition, in order to encourage the students who want to be researchers and engineers, the practical researches (Note) must be properly evaluated in university personnel evaluation systems or in academic societies, and the research system at universities that greatly influence the human resource training must be improved. Therefore, we propose the following research themes and promotion of a research system focused on practical research to train human resources.

1. Research on "new network architecture"
   - Construction of models and theories on Internet and traffic behaviors
   - Basic research on new network architecture free from the current Internet architectural concept
   - Construction of large-scale, parallel, and integrated simulator and its application in order to study the architecture

2. Research on "network dependability"
   - Research on ensuring stability and credibility as an important social infrastructure and its evaluation
   - Research on highly credible network assuming large-scale disasters and its evaluation method
   - Network architecture considering energy conservation

3. Research on "network information credibility"
   - Research on information credibility
   - Research on the social system affecting the information credibility

The research subjects in the IT, especially in the network field, have been chosen in order to meet the user's practical requirements such as data sharing, safe communication, fair and effective bandwidth use etc., and it is rare case that pure scientific research has created new application or practical use. Therefore, it is necessary to watch out such features to provide funds accordingly. For that purpose, it is useful to improve R&D in accordance with a series of process including extraction and arrangement of social needs and user's demand, and subsequent demonstration experiment and practical use.

(Note) The "practical research" here means research activity in which theories and ideas are applied, software system for practical use is implemented, actually used, studied, and evaluated in the network, or a research work in which the software, based on the findings or ideas of which theoretical proof is not clarified but obtained empirically, is implemented, used, and evaluated.

## 84. Challenge for Constructing Science for Production and Utilization of Knowledge - Realizing Knowledge Production and Utilization System Supporting Knowledge-Based Society - 【Executive summary in English】

In the knowledge-based society, there is no question that the production and utilization power of valuable knowledge becomes the resource for competitiveness. In modern days, the influence of rapid technical advancement of ICT and others in knowledge production and utilization cannot be ignored. The know-hows or techniques of knowledge production and utilization of today have been proposed in various ways based on experience, however, the proposals so far are limited to the aspects easy to approach technically with narrow applicable range and no scientific evidence. The knowledge required for the technology useful for production and utilization is the scientific understanding which eyes on and targets the dynamism of the human and organization intending to produce and utilize knowledge, and the technologies with which the human and organization who have a variety of demands can handle proactively. The construction of this scientific system is difficult, however, and it is necessary to carry out this challenge strategically in order to directly access the resource of the competitiveness.

Up to now, the research on knowledge production and utilization can be categorized into two large flows. One is the research on the human and organization relating to the collective knowledge creation in human organizations. In this approach, theory construction has been made based on step-by-step case studies and observations. The other approach is the research on applying information processing technology using computer for knowledge production and utilization. This approach is based on the information processing technology using computers and has contributed to the development of machine learning, data mining, the application of statistical mathematical science, and the research of algorithm. However, the two research flows described above have been handled separately by respective researcher's communities of different "field" for their academic concern.

If the science for producing and utilizing knowledge can be created by integrating these two flows, the knowledge required in the real world is expected to be produced and utilized in the integration process. The frontier of new scientific technology, driven by social needs, can be opened up through the integration across the existing research fields.

## 85. Dependability of Information Society - Target Concept of Information Technology -【Executive summary in English】

As represented by the Moore's Law, the information technology up to this day has intensively pursued the "improvement of performance" including speedup, capacity increase, integration increase, functional improvement and low power consumption, as a target for the R&D. As a result, information systems have penetrated deeply and intricately into the society, so called "Information Society" is created where every activity between human and organization is heavily relying on the networked information system. In the information society, it is unable to draw a clear borderline between the information systems and the social system, and the information technology and the social technology function together for the system development and implementation.

Considering the prospects of the future matured information society under these circumstances, the direction for the R&D on the information technology – as a national science and technology policy – should not be the conventional "pursuing improvement of performance" but be the "pursuing dependability." The "dependability" is a technological concept that serves the core part of the safety, credibility and security in the information society, which is the universal philosophy for the science and technology in plotting the grand design of the future information society.

In the information society, when an event contradict to the expectation and understanding of the society is once occurred, such as the system failure, serious infrastructure accident, cyber terrorism, information leakage, etc., it may bring in serious situations as property loss, fatal accidents, paralysis on social and economic systems, etc. Even worse, the situation may become the threat to the national security. The society we should aim at is a dependable information society where people and organizations can trust the quality of services (dependability and safety) provided by the social infrastructure and information environment in order to realize a safe-and-peaceful life and satisfactory activities relying on the quality services.

However, we are facing with various risk factors that may block the dependability of the information society including black box, complicity and hugeness of system, minuteness of VLSI, explosive increase of information volume, diversification of services, aging of system elements, and uncertainty of responsibility in the network.

These factors will further increase in the future along with the advancement and development of the information society.

In order to realize the dependability of the information society and establish a permanent social safety, credibility, and security assuming the presence of these risk factors, it is necessary to realize the dependability and evaluation for each of the following four classes composing the information society:

1) Backbone networked "Information system";
2) Social "Important infrastructure" constructed by the utilization of information system;
3) "Services and information" provided by the utilization of important infrastructure; and
4) "Information society" created by the people and organization receiving the service and information

For that purpose, we propose a comprehensive and basic R&D that should be carried out strategically and permanently for each of the four classes in following aspects:

i. An architecture that assures dependability permanently;
ii. Design and maintenance technique assuming life cycle risks;
iii. Quantitative evaluation technique for dependability.

In addition, in order to promote the R&D strategically and intensively in long-term viewpoint, we propose to establish a R&D base for handling basic assignments on safety, credibility, and security of the information society.

## 86. Basic Research on VLSI Dependability - Construction of VLSI Basic Technology Assuring High Credibility and Safety -【Executive summary in English】

VLSI (Very Large Scale Integration) dependability signifies a feature that a system with embedded VLSI is always operational without uneasiness. The present society depends on the highly sophisticated information system. The service provided by the information system must be of high quality and credible for our human life and society. The VLSI is an important electronic device that supports the current information system.

The present R&D intensively pursuing the transistor size, processing speed, memory capacity, and high-performance has brought the advancement of the VLSI technology. Due to this steady technological development, the life of the present society is getting more and more dependent on the VLSI technology. However, the VLSI downsizing trend is approaching to the physical limit. As a result, the difference and statistical fluctuation during the manufacturing process cannot be ignored along with the problem of malfunction due to cosmic rays. In addition, because of the advancement of the VLSI, the processes for VLSI design, manufacturing, and inspection have become complicated, which brings in degradation of dependability due to human errors, malicious attacks, stealing privacy information, and unexpected behavior of mutual reaction between complicated VLSI system elements have become the serious threat to the information systems.

In order to cope with these new threats and satisfy the expectation of the social needs – more and more dependent on the information system – ensuring dependability is necessary in addition to high performance features for the R&D of the VLSI technology. Through the adoption of these strategies, Japanese cutting-edge VLSI technologies can be maintained vividly and new science and technology frontier can be opened up.

In order to maintain the VLSI dependability, the development of the following aspects is required: new technology for vast amounts of process flows covering design, manufacturing, and implementation; specification preparation technology assuming human errors; operation error reduction technology; and malicious attack control technology in addition to the R&D in various phases from device level to system architecture level. In order to implement the dependable VLSI, the R&D on dependability evaluation technique and life-cycle design technique must be conducted.

For the R&D on VLSI dependability, the R&D for individual theme alone is not sufficient, so that all the relevant technologies for realizing dependable VLSI should be integrated and a PDCA cycle should be maintained.

## 87. Promotion of Information Security Integrated Research - Integration of Technology, Legislation, and Operation Management -【Executive summary in English】

This strategic initiative proposes a new attempt that integrates technology, legislation, and operation management as a R&D method for information security. Specifically, we propose an R&D project formation involving information communication engineers, information system operation administrators, and legal experts to promote the R&D for the assignments extracted by studying the information security issues based on the integrated aspects of the technology, legislation, and operation management.

Information system is closely connected to the society and organization as an important social infrastructure, which is indispensable for our life and social economic activities. Under these circumstances, such information security issues as leakage of important information and individual information from administrative organs and enterprises are becoming a social problem. These problems are detachable from the social and organizational system and must be examined comprehensively including the state of system, regulation, and operation.

However, it is hard to say that there is an organic coordination since the present R&D are independently carried out in terms of technology, legislation, and operation management. Thus, this strategic initiative proposes the promotion of R&D by integrating the technology, legislation, and operation management. In order to make the point of this proposal clear, examples of the service business relating to information security are shown as follows:

(1) A service provider, as a person in charge of promoting the project, who is to promote the service business will organize a project through the integration of the industries, universities, and government for the targeted service under the support of the ministries regulating the service business. In the project, information technology engineers, information system operation administrators (from government and industries), legal experts will extract issues by studying the information security issues together through the integration aspect of technology, legislation, and operation management based on such problems as social system problems and privacy problems that found in the past demonstration test for the services. For the issues extracted, the R&D and the study will be carried out based

on respective aspect of technology, legislation, and operation management.

(2) In order to eliminate the uneasiness for the privacy issues, the achievement of R&D will be studied by constructing a prototype system in cooperation with industries, universities, and government, and tightening or relaxing the regulations in a test bed (e.g. specific district).

(3) It is important to continuously carrying out the studies incorporating the changes of social values since the social values and people's mind are expected to change when various services are practiced in the society. Therefore, continuous R&D is proposed, repeating the process as: research, design, and construction; provision and use; evaluation; and re-design.

Although the significance of information security R&D is well recognized, the number of researchers in the field is not enough right now. We propose to train engineers who would be able to study comprehensive information security under the promotion of this strategic initiative.

## 88. Construction of Information Technology System for Securing the Safety and Credibility of the Information Society - For New Dependability - 【Executive summary in English】

This strategic initiative is to propose a promotion of comprehensive R&D strategy of new information technology system that ultimately values "New Dependability" for assuring the safety and credibility of the information society and enforcing the international competitiveness. The "New Dependability" here means a concept that covers the integration of dependability and security technological fields as well as the relationship with the social system. The "New Dependability" is a universal concept which the information technology should always pursue.

The present society relies on highly advanced information system, and it is no doubt that the dependability should be much higher. Therefore, the service provided by the information system must be of high quality to which the activities of human life and the society can rely on without anxiety. The information handled there should be correct and consistent, and the secrecy of the information must be kept according to the rule. Conventionally, there have been two streams in these researches, dependability and information security. There are many technical fields common to both streams, and it is required to establish a technological system by integrating these two streams in order to truly realize the safe and security society. As this field is deeply connected to the society, it is necessary to have a broad view involving the social system in addition to pursuing technological aspects.

The requirements that the information system should fulfill can be consolidated into following three: "New Dependability"; Figure of Merit (performance per unit energy consumption); and cost. The information systems to this day have been mainly pursuing “the Figure of Merit/Cost.” However, the semiconductors are approaching to the limit in physical minuteness, the software are becoming complicated and large in scale that may surpass the human ability, and the assurance of accuracy, consistency, and secrecy of information has become more and more difficult. From this viewpoint, although the necessity of pursuing "Figure of Merit/Cost" may be unchanged in future, it can be said that we are approaching the time for shifting our effort toward the direction that puts more emphasis on the "New Dependability"/Cost. This will create new additional value and market leading to the strengthening of industrial competitiveness. From this viewpoint, this strategic initiative defines the "New Dependability" as a new concept, and advocates the promotion of the field integration.

The strategic initiative proposes detailed research themes and promotion method for the modeling and evaluation method for "New Dependability", and the technique and system design for the realization.

As an examination of extremely broad range is necessary for the "New Dependability", more specific strategic proposals are scheduled to be issued for each technological field in future following the strategic initiative.

## 89. Dependable OS for Embedded System【Executive summary in English】

Computer systems are built in most of the products, equipment and infrastructures equipped or used with the electrical machinery, apparatus, and electric devices such as surrounding information appliances, portable equipment, automobile, social infrastructures such as traffic system and power networks. The basic software for such computer systems (Embedded system) is "embedded OS (operating system)" which is invisible but plays a critical role for supporting the information society.

The direction to which the conventional embedded OS technology has pursued is to seek the advancement of stand-alone information system. In this technological field, Japan has maintained its leading position. However, the demand for the embedded OS from the society is changed to the realization of the dependability of networked open systems, while supporting the rapid advancement of the information system. Although it may be difficult to change the direction of the R&D for realizing the dependability in the open network environment while supporting the advancement of information society, we must change the direction of the research in response to the requirement of the society. The challenge to this new R&D may result in opening up the new science and technology field, and allowing Japan for maintaining the competitive edge in the embedded OS technology into the future.

To realize an embedded OS with dependability, it is necessary to invest in the R&D for the high security assurance technology, real-time assurance technology, high-reliable assurance technology that operates stably even at heavy load, and the reliable software creation technology for bug-free software. Since the technology to be developed must be practical one, we must invest in the R&D that shows prospects while proceeding the basic R&D, producing a prototype with an open source software, executing a demonstration test, and requesting the industrial society for participation. Under the powerful R&D management, it is necessary to establish a R&D formation by making a team of researchers from universities or independent national laboratories in cooperation with the industries.

## 90. IRT – Integration of IT and RT【Executive summary in English】

IT (Information Technology), rapidly progressed in the past 20 years, has created an information world called cyber world. Although the research on uniting this cyber world with the real world is intensively carried out, the advancement of IT for real world application will have a limit if the IT research is carried out only within the IT world. On the other hand, robotics (RT*) has made a remarkable advancement and reached a stage where human thinking, movement, and action can be assisted, strengthened, and replaced. It is an important direction for the future to invest in the research activity for developing new technology that would bring in remarkable spreading effect, break down the IT limitations, and unite the real world with the cyber world. We call the new technology, which combines the advantages of IT and RT, IRT (Information and Robotics Technology).

The social visions such as "Healthy and comfortable life", "Safe and peaceful society", and "Sustainable economic development" can be realized by using the achievements obtained through the integration of the real world and the cyber world centering on the human and society. This strategic initiative refers these "Technological system for realizing the social vision" as "IRT platform" and proposes the R&D (research and development) of the IRT platform for realizing the vision.

Since the research on IRT is highly integrated, it is necessary to set up a system for funding cooperatively between multiple ministries in the national level and for making a research system initiated by a team composed of industry, government, and university.

From the international viewpoint, Japan has advantages in the IT and RT fields, and hence, it is currently important to execute a research program that realizes the IRT – containing the IT and RT merits – in the national level while taking care of the significance and the research system described above.

* The definition of "RT" here is broader than the conventional robotics technology. It is "the technology realizing the function for the real world."

## 91. "Real Environmental Dynamic Cutting-Edge Measurement for Inter-Facial Phenomena" Supported by the Cooperation between the Dynamic Observation and the Modeling - "See What's Invisible" for Realizing Non-Deterioration Environment and Energy Materials - 【Executive summary in English】

In the U.S, Mr. Obama assumed the presidency in January, 2009, and the Green New Deal policy will be enforced. From an international viewpoint, the environmental and energy technology will surely become the core of the future industry. In order to promote the utilization of natural energy and energy-and-resource conservations, it is required to realize a non-deterioration large size device that enables handling the energy spread thinly.

However, to realize such devices, it is necessary to get over the gigantic spatial and time gap presenting between the product and deterioration phenomenon. For example, the size of a large area device is in meter order while the defect formed on an interface, the source of deterioration, is sized in atom or molecule level. The mechanism of which chemical bonding is cut by light must be analyzed in femto second (fs: $10^{-15}$ seconds) order, and the life duration of non-deterioration material must be in 10 year order. To overcome the spatial and time gaps in such a large area device, it is necessary to heighten the superiority of manufacturing technology of Japan which is precise and credible, through the development of cutting-edge manufacturing technology that would picture "Dynamic Image" for appealing human imagination and intuition.

Thus, we propose "Real Environmental Dynamic Cutting-Edge Measurement for Inter-Facial Phenomena" supported by the cooperation between the dynamic observation and the modeling. This "Real Environmental Dynamic Cutting-Edge Measurement for Inter-Facial Phenomena" is a new measurement approach for predicting the deterioration caused in macro level by measuring the nano process dynamically on the interface under the real environment in the reproduced manufacturing process or the state of use. Specifically, this is a method for obtaining the findings and scientific knowledge for filling the two gaps – size and time – from nano to meso on the one hand, and from meso to nano on the other hand, in cooperation with the measuring method and modeling while aiming at the creation of the manufacturing process capable of nearly-perfect interface control. It will be possible to obtain the direction for practical solution against the deterioration only after enabling the measurement of integrating scientific knowledge of atomic and molecular level, and associating the phenomenon between the nano scale and macro scale.

## 92. High Throughput Cutting-Edge Measurement for "Monozukuri" Innovation【Executive summary in English】

Most of the cutting-edge industry sectors including nanotechnology, bio, and semiconductors, the measurement technology is the key point for international competitiveness. In the U.S., it is presumed that even the semiconductor industry alone spend nine billion dollars per year for the measurement devices. Because of the mass retirement of skilled labors and the labor force decrease due to the depopulation, the new product development and the productivity, advantage of "monozukuri" industry of Japan, are predicted to deteriorate. The most serious point is that the measurement technologies as the base for the improvement of R&D, product quality, and process yield have not gained the international competitive edge, even worse, the analysis devices, used to enjoy the competitive edge, are losing the power in the world market.

The "High Throughput Cutting-Edge Measurement for "Monozukuri" Innovation" is aiming at establishing the system concept for advancing and speeding up the measurement technologies indispensable for the reinforcement of the world competitiveness in R&D and "monozukuri", and aiming at developing and integrating the elemental technologies to realize the concept.

Based on the concept incorporating the advancement of the latest electronics, IT, and robotics, a high-throughput measurement system superior in size, operability, high-speed, and reliability must be designed, and developed in order to prevail in the R&D and "monozukuri" sites and to obtain standardization. Specific R&D assignments are as follows:

1) Construction of high-throughput technology concept and search for breakthrough technology

- Clarification of detailed system concept aiming at speeding up the "monozukuri" time – 100 times or more – centering on the new material, raw material, and device development through the revolution of measurement time and time factor, as well as the clarification of technological composition and significant integration fields
- Presentation of high-throughput measurement elemental technology containing innovation and feasibility

2) Microminiaturization of measurement devices

- Utilization of cutting-edge machining technology for microminiaturization such as MEMS, and NEMS
- Development of a system based on the new physics and chemical principle for microminiaturization
- Application development for "monozukuri" site and portable measurement machine reflecting the microminiaturization

3) Measurement of ultrahigh speed
- Development of breakthrough technology for ultrahigh-speed measurement including high sensitivity and high luminance
- Development of high-speed adjustment and scanning measuring technology of measurement sample
- Development of multipoint (multi-channel) simultaneous measuring technology based on multi-probe, multi-beam, and so on

4) Hybrid measurement
- Development of synthesis and analysis direct coupled measurement system integrating samples and sensor array

5) Compound (structure and physical properties) measurement
- Development of simultaneous measurement system of layered structure from nano to macro in size
- Development of compound measurement technology of various physical properties
- Inspection technology for the quality control, safety, and credibility at shop floor (or simulated environment)

6) Informatics of measurement information
- Development of information processing technology and international standardization composed of massive data high speed processing, visualization, database, and data mining of the high throughput measurement

## 93. Deterioration Diagnosis and Life Management Technology of Social Infrastructure【Executive summary in English】

The social infrastructure, constructed in the period of rapid economic growth, is rapidly aging. It is very likely that social infrastructures using for many years will be damaged and destructed unexpectedly, which may result in serious damages to the life or assets of people. Even ending up in no troubles, the convenience of life may be lost.

To utilize the social infrastructure safely for many years, it is important to correctly measure and diagnose the type, location, and degree of the deterioration to predict the exact time of occurrence of the damages, and it is necessary to develop a technology that traces back to the cause of deterioration instead of conventional and empirical inspection and diagnosis technology.

The "Deterioration Diagnosis and Life Management Technology of Social Infrastructure" advocated in this strategic program means the measurement and diagnosis of the aged deterioration for the lifelines that support the life of people such as roads, bridges, railways, electricity, and water services, and the deterioration for the facilities that may intensely impact on the social activities and may give serious damages on people at the worst, in order to ensure the safety by detecting the symptom of the damage and destruction earlier than in the past by the evaluation of the life expectancy which is reflected on the maintenance, reinforcement and upgrade plan.

This technology is composed of following technologies: a technology relating to sensor and data processing of nondestructive measurement and diagnosis for the deterioration and damages of facilities; a technology for predicting the life expectancy according to the operating stress or external force such as earthquakes based on the deterioration phenomenon model, the damage marginal valuation model, or the combination of the models; a technology for monitoring the symptoms of damages and destruction in full-time basis; a technology for arranging sensors optimally; and a technology for data communication processing.

A part of elemental technologies including the deterioration model or the destruction limit evaluation model that determines the damage or destruction of facilities resulting in deterioration, has been independently developed. However, as a whole, it is necessary to develop and advance the elemental technologies, insufficient for highly credible life expectancy prediction or detection of damages and destruction, and to incorporate the data obtained in fields into the technologies to construct a system. Many of social infrastructures are maintained and managed by the state, local governments, IAAs and other public organizations, however, in many cases, the technical transactions of the maintenance and management are outsourced to private sectors. Especially, it may be difficult for private companies to independently promote the technology which is strong in its basic and commonness features and is including the basic research such as measurement principle and deterioration model, therefore, it may be reasonable for the government to take initiative from the viewpoint of taking full responsibility of the maintenance and management for social infrastructure.

By carrying out this proposal under the leadership of Japan, accidents can be avoided by detecting the symptom of damages and destruction earlier, and the aged social infrastructures can be appropriately fixed or replaced by diagnosing the life expectancy precisely, which will contribute to the improvement of safety and reduction of social economic load. In addition, the elemental technology for deterioration measurement and diagnosis as well as the modeling for deterioration mechanism may be advanced, which will enable the prediction of deterioration phenomenon at an environment difficult to measure directly.

## 94. Boosting Social Innovation through Collaboration between Industry and Universities【Executive summary in English】

As the world is becoming more globalized, Japan faces a more competitive environment. Emerging countries are growing their economies rapidly while advanced countries are losing competitiveness. Multinational corporations are increasing their presence in the global market as well.

Japanese society is also changing. The birth rate is declining and the population is aging rapidly, and experts warn that hundreds of municipalities could disappear in the future. Furthermore, the number of Japanese who feel uneasy about the future is increasing. It is expected that growth and development of Japan would contribute to improving the quality of life of individuals.

Amid dynamic changes in social conditions both inside and outside of Japan, science and technology-based innovation is increasingly required to create new value and make changes in society for the better. There are two conditions to boost innovation: industry and universities should seriously team up; and social activities should be promoted to create a better society.

To boost social innovation through collaboration between industry and universities, developing new products and services for the global market with cutting-edge research and technology is not the only thing, but creating a better local community with known technologies is also significant. Industry, university, the government, municipalities and local communities should all seriously team up and make changes in both global and local communities for the better.

Let’s take an example. The bus services were terminated in a rural small town which struggles to deal with a declining birth rate and an aging population. While buses remain an important mode of transportation for the residents, the town is not able to provide a regular service due to their financial conditions. The unavailability of bus services leads the aged residents to avoid going out, which causes their health to deteriorate, and, as a result, increase the financial burden of health care on the town. One of possible ways to address the problem is to provide on-demand bus service. Information and communications technologies (ICT) can provide a traffic management system to improve convenience for the residents and reduce the running cost. Setting up events and places to visit will stimulate the residents to go out, and enhance communication between them as well as reduce the medical costs.

Such a social innovation is not created by the town municipality alone, but by teamwork with industry and universities to contribute to demand system development, along with the government and funding agencies to support the service development, and the residents of the town. A person or an organization is also expected to join the team and function as an association between different team members. Furthermore, it is required to develop the next generation of the leaders of the town, to share the experiences with others both inside and outside of Japan, and to improve collective performance as well as demand systems and transportation services in different places.

To boost social innovation through collaboration between industry and universities, basic, applied, and development research should be conducted concurrently and coherently, and the findings should be implemented through field experiments. An integrated system needs to be established for implementing all of these activities to achieve the vision of the future.

The integrated system should provide an optimal environment for teamwork between industry and universities and also with the government, municipalities and local communities. Collaboration between small and medium enterprises and universities in each region is crucial to revitalizing regional economies. Some policy measures are needed to strengthen collaboration between industry and universities as well. Industry investment in university research should be promoted to secure university research funds across Japan. It is also essential to develop skilled human resources for innovation in industry.

This proposal recommends three policy priorities and actions, supported by evidence from a case study of 30 successful projects both inside and outside of Japan. The leaders are strongly expected to emerge from everywhere including industry, universities, government and municipalities, funding agencies and local communities, then take action to make changes in society for the better.

## 95. The Age of Team Collaboration - Boosting Innovation through Collaboration between Industry and Universities【Executive summary in English】

Further innovation is required to ensure sustainable economic growth and social development. More scientific ideas and technologies should be transformed into new values in society. Universities, industry and government in Japan have promoted collaborative activities for innovation, but it cannot be said that they work well with each other and maximize their innovation functions.

To boost innovation through collaboration between industry and universities, all involved parties should seriously team up. Collaboration should be deepened to address domestic and global threats such as our low birth rate, an aging population, and environmental concerns, and to break up stagnant conditions to encourage economic revitalization.

The 18 case studies in Japan and abroad demonstrate that three actions are needed to boost innovation through collaboration between industry and universities: (1) Find a partner to team up with; (2) set up an innovation team; (3) facilitate an environment that enables industry and universities to co-create innovation.

This proposal recommends that universities, industry, government and funding agencies promote the activities listed below, and sets goals to boost innovation through collaboration between industry and universities.

(1) To find a partner to team up with.

- Universities should improve global research competitiveness and make attractive proposals to industry.
- Industry should overcome the “not-invented-here” syndrome and discover promising ideas and technologies in universities.
- Government and funding agencies should encourage the process of matching the needs in industry with the expertise of universities.

(2) To set up an innovation team.

- Universities should attract the necessary research talent and support specialists across departments, and should create an international network of excellence (NOE) with both domestic and foreign organizations.
- Industry should make a concerted effort to invest strategically in collaborative research with universities.
- Hence, universities and industry should share visions and strategies, and build and manage innovation teams.
- Government and funding agencies should increase funds to encourage universities and industry to co-create innovation and attract the human resources necessary for innovation teams.

(3) To facilitate an environment that enables industry and universities to co-create innovation.

- Universities should cultivate talent for future innovation, and should make greater contributions to innovation in communities.
- Industry should improve personnel systems to accelerate innovation, and

should cooperate with universities to improve the education system.

・Government and funding agencies should increase the global research competitiveness of Japan, and should accelerate strategic collaboration amongst industry, universities and the government as well as the cultivation of talent for future innovation.

## 96. Looking beyond the 2020 Tokyo Olympic and Paralympic Games 【Executive summary in English】

These recommendations are compiled with the following points in mind:

- The 2020 Tokyo Olympic and Paralympic Games (TOP) provide a vital opportunity for various socio-economic system reforms for the realization of a sustainable society in the 21st century.
- During preparations for and operation of the TOP, we can present possibilities for synergy between the Games and technological innovation.
- The TOP is an opportunity for going beyond the bounds of academics to promote the future relationship between society and scientific technology, and for actively stimulating further opinion from scientific and technological communities.

The focus of the TOP is of course the athletes, but when considering the relation between the Olympics and science and technology it is important to recognize the significant synergies that are in play in areas such as broadcast technology, IT, security, disaster prevention, and environmental management.

There is a vital need for Japan to rapidly transition from being a 20th-century society of mass production, mass consumption, and mass disposal to a 21st-century society of increased efficiency and low environmental impact, and 2020 is positioned as a critical turning point for Japan. We should establish 2020 as a milestone for completing systemic preparations for conversion to this new socioeconomic system, thereby accelerating research and development that will contribute to hosting the TOP. To prepare for what comes after 2020, we should consider the following:

1) Infrastructure development, which is the obligation of the host country, should be performed in consideration of resilience to both natural and manmade disasters. Bearing in mind that the Games will be hosted at a turning point for society, both private finance initiatives and public–private partnerships should be actively employed and policy development should aim to induce innovation in existing infrastructure and social systems so that economic and social effects persist after the Games are over. In addition to scientific and technological innovation regarding traditional Japanese culture and values such as compactness, functionality, and environmental harmony, we should work to accelerate the research and development that will be needed to solve mid- and long-term social issues, such as increased energy efficiency and modernization of transportation and communications infrastructure, promoting consideration of such issues from the perspective of the social sciences.

2) We should work to share the values of globalization represented by the Olympic Games. Four billion people will watch the Games via television and the Internet, and we should aim at dazzling them with the cutting-edge technologies that are

the result of industry and academia working hand-in-hand. We should strive to provide easy access to traffic, weather, and tourism information to the many international tourists who will attend the Games, by developing Internet-based information services that harmoniously blend humans and cyber-physical systems.

3) Hosting the Paralympics provides an opportunity for promoting technological innovation aimed at social inclusion of the physically challenged and the elderly, and we should also keep in mind that such technological development can transition to areas where it serves to improve the lives of the general population.

4) To prevent effects of TOP 2020 from transiently ending after the Games, it is important that we foster the development of youth who will become active players on the world stage, not just in sports but in all fields. We should make strides to provide increased opportunities for international experience to the high school, college, and graduate students who will form the next generation of researchers and technicians, for example, through study abroad programs and participation in events such as the International Science Olympiads, the WorldSkills Competition, and robotic competitions. It is also necessary to work toward developing opportunities to show our elementary and junior high school students how science and technology can provide the same excitement, dynamics, empathy, and urge to participate that athletics does.

5) Olympic and Paralympic athletes set goals for themselves, not limits, and this is an important attitude for scientists and technicians to share when faced with the many problems stemming from issues related to finite resources. Science provides a boundless frontier, and it is important that we maintain our enthusiasm for solving the problems of limited resources while nourishing an integrated perspective that considers the pros and cons of applying technology to society. Furthermore, 2020 will be the beginning of a new era where not only physical human activity but also some aspects of decision-making and thinking will be supported by machine- and computer-based intelligence, and decisions regarding what activities to relegate to robots and computers will be vital. We must therefore remain aware that human capabilities for thinking and decision-making will become all the more important as we take on new scientific and technological research and development.

6) Public interest in areas such as sports science and health science will likely increase as we head toward 2020. In these and other fields, it is necessary to increase opportunities to see and experience innovative technologies that benefit society, thereby lowering barriers between the scientific community and the general population. It is necessary that we strike a national dialog regarding how technology should be employed, what societal rules we should create or amend, and what kind of society we hope to create, and when doing so we

should aim for the active participation of persons from the humanities and social sciences.

7) There is a national consensus that returning victims of the Great East Japan Earthquake to their normal lives should be a prerequisite for hosting the TOP. It is therefore highly desirable that the recommendations outlined in the "Proposal for Recovery from the Tohoku Earthquake" (Center for Research and Development Strategy, Japan Science and Technology Agency, May 2011) should be implemented.

## 97. R&D Funding System for Issue-Oriented Innovation - Networking and Organizing R&D Capabilities-【Executive summary in English】

Japan's public R&D funding system as well as those of other nations has undergone great changes recently. A common theme for all nations amid the huge societal changes being caused by globalization is to redesign their R&D funding systems from the viewpoints of both international competition and international collaboration. At the same time, each nation has been introducing reforms to focus on innovation and strengthen accountability. In Japan, stagnant total public R&D investment, decreasing regular funding, increasing competitive funding, etc. are influencing the management and research activities at universities and public research institutes in various ways. Public R&D funding is now drawing much attention and, particularly since the last year, important policy documents and proposals on this theme have been drafted by various stakeholders.

Meanwhile, there is now strong expectation in Japan that science and technology should contribute to the solution of many societal problems which the nation faces, including prolonged economic stagnation, declining international competitiveness, aging population, environmental and energy concerns, and recovery from the catastrophic disaster in March 2011. The 4th Science and Technology Basic Plan, established in August 2011, made clear that the solution of societal problems was one of the basic directions of Japan's science, technology, and innovation policy.

This strategic proposal presents concrete measures necessary for reform effort to construct R&D funding system that corresponds to the new goal of accelerating issue-oriented innovations. The fundamental concept here is to shift the basic direction of R&D funding from the formation of competitive environment to the networking and optimum organizing of research and innovation capabilities, thereby tapping the nation-wide potential and ensuring that researchers and specialists in a broad range of fields can exercise their capabilities to the full extent. The proposal consists of the following items.

- (1) Designing efficient R&D funding based on nation-wide perspectives
  - (1)-1 Roles and responsibilities of funding agencies
  - (1)-2 Roles and responsibilities of PD/PO
  - (1)-3 Effective use of equipment
- (2) Drastic strengthening of R&D organization
  - (2)-1 Social responsibility of researchers
  - (2)-2 Stabilizing the R&D organization
  - (2)-3 Ensuring human resources

(3) Establishing the R&D evaluation system to promote issue-oriented innovations

(3)-1 Introducing the scheme of step-by-step review

(3)-2 Improving the effectiveness and reliability of R&D evaluation

The role that R&D funding plays in the implementation of national science, technology, and innovation policy is extremely important. Funding agencies, which are the main implementing bodies of the proposed items shown above, should reinforce mutual collaboration, ensure close cooperation with the government and the scientific community, win the involvement of the private sector and other stakeholders, and vigorously push forward their efforts to realize the reform.

## 98. Toward the Establishment of Principles Regarding the Roles and Responsibilities of Science and Government in Policy Making 【Executive summary in English】

The government makes policies using scientific knowledge in a broad range of fields. Science can provide an important basis for ensuring the validity and reliability of decision making. In the 21st century, as the relationships of science and technology to society and economics are greatly increasing their complexity and uncertainty, the role to be played by science in the process of policy making will continue to grow.

Recently, efforts to ensure the validity and reliability of science-based policy making have been made overseas. In the United States, while rules concerning the process of scientific advice have long existed, the Obama administration is accelerating the effort to ensure scientific integrity in the government. In Great Britain, various principles regarding science in policy making have been established since the BSE crisis in the 1990s. In many other advanced nations as well as international organizations such as the European Union (EU) and Inter Academy Council (IAC), similar efforts have been made.

In Japan, the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Station accident in March 2011 have prompted the examination on the roles and responsibilities of science and government in policy making. The 4th Science and Technology Basic Plan, adopted by the cabinet in August 2011, specifically mentioned the need to examine the relationships between science and technology and policy and to establish basic principles on this issue This proposal presents draft principles on the roles and responsibilities of science and government in policy making. This draft is intended as a starting point for discussion among a wide range of stakeholders to raise awareness of the importance of this issue and refine the rules on science-based policy making. Through such discussion, the government should establish the principles, and relevant organizations should then consider drafting their own guidelines. The draft principles in this proposal consist of the following items.

(1) The role of scientific advice in policy making
(2) Seeking scientific advice in a timely and pertinent manner
(3) Ensuring the independence of scientific advisors
(4) Awareness of responsibility as scientific advisors
(5) Achieving broad perspectives and balance

(6) Ensuring the quality of advice and integrating opinions
(7) Proper handling of uncertainty and diversity
(8) Free disclosure of scientific knowledge
(9) Even-handed treatment of scientific advice by the government
(10) Ensuring transparency of the scientific advice process

This proposal also presents measures necessary for laying foundations for science-based policy making. For example, efforts to create mechanisms for scientific advice in emergencies, ensure the enforcement of the principles and guidelines, and foster education concerning the relationships of science and technology to policy and society are necessary. Through such efforts, along with organizational reforms now being considered by the government, the effectiveness and integrity of science-based policy making in Japan should be secured.

## 99. Proposal for Recovery from the Tohoku Earthquake -from the viewpoint of science and technology-【Executive summary in English】

## 100. Emergent Proposal on the Tohoku Earthquake -Prompt Implementation of Damage Surveys and Their Fulfillment-【Executive summary in English】

This proposal summarizes the contributions we can make and what we should do, mainly from the viewpoint of science and technology, to recover from the Tohoku Earthquake.

The multiple catastrophic disasters caused by this earthquake are pressing us to fundamentally transform Japan's social and economic structures, change our sense of values, and present global challenges in the 21st century. The reconstruction of the affected areas requires a combination of the forces of many fields, organizations, generations, and nations. Science and technology can also significantly contribute to the reconstruction.

Basic Ideas about the Use of Science and Technology

1. Reconstruction activities require a combination of expertise from many scientists.
2. By working collaboratively with municipalities, victims, and others in disaster-stricken areas, scientists can find ways to make effective use of their knowledge beyond their individual fields.
3. An amalgam of regional culture and tradition and the latest scientific/technical knowledge provides true reconstruction.
4. Through the use of the said knowledge, we can create robust, adaptive scientific knowledge that is required by future reconstruction activities and that is also capable of breaking the barriers of organizations and systems and is capable of making international contributions.
5. Through these activities, we will push forward with reforms to the science and technology systems, which were difficult in the past.
6. Scientists are responsible for providing advice and recommendations based on their expertise; they should be different from policymakers and performers in responsibility and role.

This proposal considers I "Reconstruction of the Disaster-stricken Areas," II "Future

Energy Strategy," and III "Future Responses to Disasters," and presents recommendations. Particularly important points are listed below.

## I. Reconstruction of the Disaster-stricken Areas

[Participation of scientists]

1. To identify the needs and social expectations associated with reconstruction activities and develop and carry out plans, many scientists must participate in research and study activities in conjunction with regional communities.

[Damage investigations and follow-up researches]

2. We propose that an international organization be established to study the long-term impact of radioactive substances on the environment.
3. We propose that facilities for storing and analyzing the record of the earthquake and archives for survey findings be set up.

[Contribution to the reconstruction of regional communalities]

4. To treat and clean up the soil, plants, land, and water contaminated with radioactive substances, the creation of a framework for comprehensive, continuous implementation is required, while making use of overseas expertise and accumulated technological know-how.
5. The use of science and technology in creating new towns provides new approaches such as the following:
    - The design of entire systems for social infrastructures (for energy, water, transportation/distribution, and information) that use a combination of hardware and software
    - Implementation of eco-city initiatives of various scales by, for example, introducing renewable energy
    - Upgrades medical care and education by making use of ICT (information and communication technology)

[Reconstruction of research & development infrastructures]

6. Damaged research & development infrastructures must be reconstructed early in consideration of priorities. In reconstructing them, we should promote networked, problem-solving research systems beyond field, organizational, and national boundaries and enhance our methods of international information dissemination.

## II. Future Energy Strategy

7. The national energy strategy must be developed openly and research and

development activities for energy must be continuously promoted.

8. In disaster-stricken areas, we must implement show future systems that will reinvigorate local communities and act as future models for energy demand and supply.

## III. Future Responses to Disasters

9. We must ascertain why the fruits of the research and development regarding disasters and other scientific knowledge had not been implanted, and we must make improvements to these activities.
10. A disaster response system must be built which provides smooth connection between usual conditions and emergencies based on modeling and simulations.
11. It is essential to build an information and telecommunications system that is robust (resistant to changes) even in times of disaster. We must also study the relationship between information and society (reliability of information, damages caused by rumors, etc.).
12. In providing disaster medical care, it is important to provide prompt support based on effective logistics. We must also set up a control tower for medical care management.

The Center for Research and Development Strategy will continue to further consider some points so that they will lead to specific research and development challenges, budget development, and system reforms.

The reconstruction activities for this disaster require responses that make use of science and technology as a whole instead of individual techniques and pieces of knowledge. They must be also carried out as global collaboration. To meet these requirements, we must transform the scientific and technological systems in Japan into ones that can optimally combine human and other resources for solving problems beyond many barriers.

The Center for Research and Development Strategy will continue to conduct studies from these viewpoints as well.

## 101. Towards Realization of Evidence-based Policy Formation: Development of Science of Science, Technology and Innovation Policy 【Executive summary in English】

In today's society, Science and Technology (S&T) leads to innovation and contributes greatly to developments of human society. On the contrary, these developments have brought various societal challenges, including depletions of natural resources, destructions of global environments, explosions of population and expansions of income disparities. Also, in order to cope with these societal challenges, there are growing expectations for further developments of S&T and realization of Innovation.

To meet with such expectations, and under limited financial resources, Science, Technology and Innovation (STI) policy is required to develop with scientific rationality in policy-formation process; it should be formed based on evidence (scientific evidence). This evidence includes systematic observations and analysis of structures and dynamics of the society and the economy. Then, based on the observations, societal challenges to be coped with S&T should be discovered and identified. Furthermore, solutions for the challenges should be provided, with the current level and the potential of S&T. The primary purpose to make this strategic proposal, to construct Science of STI policy for evidence-based policy-formation, is to meet with these social demands.

On the other hand, STI bears uncertainty in the process and requires a long period to yield outcomes. Thus, it is difficult to analyze and evaluate the economic and social impacts of STI policy and indicate them scientifically. However, increasing the transparency of policy-formation process and assuring the accountability for the public, by providing evidences in policy-formation process to the society, are one of major driving forces to promote the Science of STI policy.

The Science of STI policy is expected to develop as a new area of study by bringing together the diverse knowledge of related scientific fields, while utilizing the research on STI policy so far. Furthermore, the research results of the Science of STI policy must not end up as developments of scientific methodologies in pure academic. They are expected to be used in the practice of policy-formation and utilized as assets of the society. To that end, collaborations among stakeholders, including policy-makers and scientific community, should be promoted.

The Great East Japan Earthquake that occurred on March 11, 2011 and ensuing massive tsunami have caused great damages to the region ranging from Tohoku to Kanto areas of Japan. The nuclear power plant accident caused by the earthquake and tsunami has resulted in the leakage of radioactive materials in the nearby area and ocean. This has led to serious damages and impacts on the economy and the society both mentally and physically. Moreover, this disaster has raised major challenges to Japan and also for the rest of the world, for creating a social system which assures people's security and safety and what role S&T should play to achieve such assurance. Accordingly, in an effort to recover from the disaster and restore Japan, it is required to reshape STI policy towards a creation of a security-assured social system in the future, by mobilizing wisdoms on the potential of S&T.

In this strategic proposal, the philosophy of the design to develop the Science of STI policy is firstly proposed. Then, the guiding principle for the realization of the philosophy is derived. Finally, the strategy to implement the guiding principle is proposed.

**[Philosophy of Design]**

The Science of STI policy should be designed based on the following philosophies:

1. **Form policy with scientific rationality**
2. **Realize rational policy-forming process**
3. **Increase transparency of policy-forming process and assure accountability for the public**
4. **Make knowledge obtained from the Science of STI policy available to the public in policy-formation process**
5. **Establish collaborations among stakeholders, to engage appropriately in policy-formation, under the defined functional roles and responsibilities**

**[Guiding Principle]**

The guiding principles to realize the philosophy are as follows:

1. **Realize co-evolution of policy-formation mechanism and the Science of STI Policy**
2. **Facilitate public participation in policy-formation process by presenting evidence-based alternative policy menu (*)**
3. **Develop the Science of STI policy through collaborations among various natural and social scientific fields. Use the knowledge which is collected, accumulated and structuralized from the Science of STI policy, as common assets of the society, to inform and guide policy-formation.**
4. **Define functional roles and responsibilities of government, science community,**

**industries and the public in policy-formation, to collaborate appropriately. Then establish code of conduct for each party.**

5. **Foster human resources who take leading roles in innovative policy-formation process and/or the Science of STI policy. Build communities and networks for them. Improve environments that enable them to be active across organizations and internationally.**

(*) In this strategic proposal, a "policy menu" is defined as a combination of alternative policy instruments with description of its estimated social and economic impacts.

**[Strategy for Implementation]**

The strategies to implement the above guiding principle are as follows:

1. **Build a comprehensive system to promote the Science of STI policy**

   A comprehensive system to promote the Science of STI policy should be built to drive forward the following items mentioned in 2 to 4. Under this system, the research results should be collected, accumulated and structuralized to inform and guide policy-formation. Also, it should examine the code of conduct of government and science community in policy-formation, in which functional roles and responsibilities for each party are defined. Then it should coordinate the participants according to the examination.

2. **Promote the research of the Science of STI policy**

   To develop the Science of STI policy, a research system should be built to correspond to specific purposes; research for specified policy-issues: research and development of new models and indicators focusing on use in policy-forming in the medium and long terms: and research for building a scientific foundation for the Science of STI policy. To promote the research, research areas (**) covered in the Science of STI policy should be defined strategically. In this strategic proposal, the research area is derived in the following procedure. The policy issues are extracted from the systematic mapping of S&T policy system, and then corresponding research agendas are defined accordingly. The research agendas are grouped to form the research areas as follows:

   **Area I: Design and implement strategic policy-formation frameworks**
   **Area II: Design and implement dialogs with society in policy-formation**
   **Area III: Measure and visualize social and economic impacts of R&D investments**

**Area IV: Promote STI system**

(**) In this strategic proposal, a research area is defined as a set of research agendas.

**3. Develop infrastructure for statistics and data for the research and policy-formation**

It is vital to enhance the infrastructure for systematic statistics and data base as a research base of the Science of STI policy, and also as a base for policy-formation. In addition, it is also necessary to enhance environments for utilizing data, thereby disclosing such data to the public as much as possible.

**4. Construct institutions and networks for education and fundamental research for the Science of STI policy**

Institutions that act as a hub to foster human resources strategically should be constructed. Such human resources include policy-makers who promote evidence-based policy-forming: researchers who pioneer and enhance a scientific foundation for the Science of STI policy: and ones who bridge the gaps of policy-formation process and the research and strive to implement research results in the practice of the society. In addition, a range of diverse career paths should be established, where those can work actively. Also, domestic and international networks among various parties should be established.

Center for Research and Development Strategy (CRDS), JST has been discussing how to develop the Science of STI policy for evidence-based policy-formation, since 2008. Based on results of the discussion, Ministry of Education, Culture, Sports, Science and Technology (MEXT) is planning to launch "Science of Science, Technology and Innovation Policy Program" from FY2011, after conducting the investigation on the institutional design with related organizations. Furthermore, the results of the discussion of CRDS has also been reflected in the "Report to Consultation No. 11, Regarding the Basic Policy on Science and Technology" (December 2010), and in the article, the promotion of Science of STI policy is mentioned.

## 102. Research into Social Wish -Discovery of Social Wish through Panoramic Observation for task-driven Innovations in the Era of Sustainability【Executive summary in English】

It is expected nowadays that scientific and technological innovations improve the sustainability. However it is difficult to elaborate definite subjects of research and development supported compatibly by science and society which meet this expectation. It is proposed here that the elaboration of research subjects should be based on social wishes that are conditioned upon both being shared by people and being scientifically assured to improve the sustainability. Research subjects based simply on scientific assurance for sustainability satisfy only necessary but not sufficient condition for sustainability. They only cover partial requests from sustainability but not all because each of disciplinary scientific knowledge only picks up subjects relevant to the particular discipline, and sometimes worsen other aspects. We shall never enumerate all research subjects necessary for sustainability if we seek them within scientific knowledge. We should turn our faces toward society in order to overcome the difficulty, enumerating them through social wishes which are less systematic as science but not disciplinary, hence possibly covering all requests from sustainability when they are detected by panoramic or disciplinarily integrated observations. Social wishes, however, are generally expressed verbally and obscure. Our proposal is implementation of a research to discover social wishes by panoramic observation in scientific way.

Social wishes which are to be the bases of elaboration of research subjects should not be of individual interests or for special benefits, but should be that recognized publicly by people. Social wishes, however, are not necessarily apparent, but can be potential. When a social wish turns apparent and shared by people, it can be an evidence for a research subject to be publicly supported. One of the most important points of the presently proposed research into social wish is to establish scientific methods to discover such potential wishes.

The discovery of social wishes suggests actions in future which are scientifically assured to improve the sustainability. Actions based on the discovery will affect society and nature to raise some changes, which are again observed panoramically and confirmed if the results are adequate. New social wishes will be detected through this confirmation. Repetitions of observations of social wishes and actions based on them create a circulative process. Such recursive structure linking science and society in a loop permits an evolutionary improvement of sustainability. Task driven innovation for sustainability must be accomplished in this structure.

As mentioned above, the research to discover social wishes includes disciplinarily integrated or panoramic observation of society and nature, forecast of wishes arising in future and realization of common understanding of those wishes among people. Consequently, collaborations among researchers of different disciplines including humanities, social sciences, physical sciences and life sciences, engineering sciences and others are requisite.

## 103. Framework for an Innovation Ecosystem Aimed at Solving Problems

This strategic proposal suggests a framework for an innovation ecosystem aimed at solving problems and basic conditions for scientists' participation in the ecosystem.

From the beginning of the 20th century, innovation has significantly contributed to the development of society, but at the same time has caused various problems that have threatened social sustainability. While advances in science and technology have improved the productivity and competitiveness of industry, various problems including global warming and environmental pollution have emerged as a consequence of our large consumption of energy and natural resources. These problems have become increasingly serious in the 21st century. It is necessary that we properly deal with not only these problems, but also problems arising in the future. Therefore, it is essential that, as a means to solve such problems, we continuously create innovation for solving problems that threaten social sustainability, in other words, "innovation aimed at solving problems".

Innovation is created through a process in which various factors such as talent, knowledge, funds, systems, and markets are related to one another in a complex manner. The process involves uncertainty associated with, for example, unexpected success or failure in research and development and the demand for new products and services. To convert obstructive factors lurking in this complex and uncertain process, we must organize a complicated environment surrounding innovation, which could be seen as an ecosystem, into a favorable system for innovation. In other words, continuous creation of innovation for solving problems requires an innovation ecosystem aimed at problem solving where constant creative activities involving various factors would lead, through their dynamism, to efficient and effective creation of innovation.

Society requires that science and technology solve problems that threaten social sustainability. It is a duty of science and technology to respond to this requirement and provide innovation aimed at problem solving. Such innovation is created through a loop involving society and full research. This "full research" consists of three aspects:(i) the detection of threats to social sustainability and the setting up of problems to be solved; (ii) the designing of solutions to the problems; and (iii) the implementation of the solutions in society, and conducting these as a whole. A loop between society and full research-where full research produces results in answer to society's requirements and where, based on the results, society has new requirements of (future) full research-would continuously advance toward the realization of a sustainable society.

The innovation ecosystem aimed at solving problems would expand globally, and the constituent players would include not only scientists, but also the government, administrative agencies, industry, think tanks, and NGOs/NPOs. Each of them plays a role in creating innovations. Through exchanges of information among and between the players and society new value is created, thereby contributing to solving problems that threaten social sustainability and the sustainable development of society.

Scientist must actively participate in the innovation ecosystem aimed at solving problems and improve the performance of the loop linking society and full research. Therefore, we must attempt to share and distribute information beyond the borders of nations and disciplines in all three aspects of full research. Moreover, diverse talent, knowledge, and funds are needed to promote the three aspects of full research as a whole. The development of facilities and equipment, regulations and standards, and systems can be an effective measure in concentrating the factors necessary for problem solving in needed places.

To promote full research aimed at solving problems, the following three aspects of full research plus the creation of an appropriate environment are necessary.

**1. Problem Setting**

- Observing scientists, in cooperation with think tanks, consider the medium to long-term prospects of future society and detect potential threats that can have serious social effects.
- Observing scientists, in cooperation with think tanks, analyze the social effects of threats from various perspectives, decompose them to find concrete problems, and set up problems to be solved.
- The government and administrative agencies regularly review prospects of future society and build a mechanism to modify or change the setting of the problems to be solved.

**2. Solution Design**

- Designing scientists, in cooperation with the government and administrative agencies, promote the development of new integrative science and technology, and build an organic link between the development of technologies and knowledge creation for problem solving.

- Designing scientists, industry, and the public sector promote industry- academia-government collaboration, international collaborative research, and the formation of consortiums and research centers to find, with support from think tanks and NGOs/NPOs, optimal relationships between the fruits of science and technology and society or safety/comfort/convenience in people's lives.

**3. Solution Implementation in Society**

- Actors consisting of scientists, industry, the public sector, NGOs/NPOs, and specialists from think tanks create an environment and systems based on the basic design of solutions through trial operations in specially designated areas.
- Through industry-academia-government collaboration and the formation of consortiums and a network of regional activities, actors internationally expand the building of an organic link between the development of technologies and the creation of knowledge for problem solving.

**4. Development of Systems for Collaborative Promotion**

- Scientists, industry, and the public sector cooperatively build a network of research and development efforts aimed at solving problems, and the public sector leads efforts to combine existing systems and constructs a mechanism in which relevant government agencies coordinate their administrative activities for promoting full research. In order to support the formation of career paths for people engaged in full research for problem solving, the public sector conducts evaluations based on the degree of contribution to problem solving and provides employment at administrative agencies or NGOs/NPOs, with help from scientists, industry, and NGOs/NPOs.
- Scientists, industry, and the public sector cooperatively build a system in which Asian countries collaborate in promoting full research aimed at solving problems, and support necessary exchanges of talent, knowledge, and funds.

Various efforts are conducted both domestically and internationally toward the realization of a sustainable innovation ecosystem that can effectively and efficiently promote innovation aimed at solving problems. Examples include foresight projects, interdisciplinary research, reverse innovation, public support for solution implementation in society, and business pursuits on a global scale.

The Center for Research and Development Strategy (CDRS) of the Japan Science and Technology Agency has been examining innovation systems. CRDS has also been focusing on new interdisciplinary research as a new tool for innovation and investigating ways to promote it. Moreover, CRDS has been advocating concepts such as science and technology-based innovation, the National Innovation Ecosystem, and the Global Innovation Ecosystem and has proposed measures necessary for promoting new interdisciplinary research. Based on these efforts, this strategic proposal suggests measures to move forward a new innovation ecosystem which is needed for solving problems that threaten social sustainability.

## 104. Strategic Proposal on the Promotional Measures for Emerging and Interdisciplinary Science and Technology - Solving Societal Issues and Expanding the Frontiers of Science and Technology【Executive summary in English】

Modern society faces an exploding number of issues expected to be solved by scientific and technological contribution. Global environment issues; sustainable development under resource, energy, environment restrictions; and the emergence of new industries from service oriented developments are just a few examples. Many of these issues are complex phenomena and are difficult to be solved within the support of a single scientific "discipline". They need to be solved by integrating science and technology beyond their disciplines. The importance of "an intensive promotion of problem solving types of science and technology" for the 4th Science and Technology Basic Plan is being recognized.

Based on these backgrounds, this proposal suggests the specific promotional measures of emerging and interdisciplinary science and technology induced by societal issues.

Up till now, the following points regarding the development process of the emerging and interdisciplinary science and technology were indicated, from the newly developed interdisciplinary science and technology examples.

(1) The process has the following two directions of "creating new wisdom and developing scientific and technical frontiers" and "creating social values and contributing specifically towards solving issues".
(2) The process integrates various approaches in chain reaction for creating wisdom and social values.
(3) The following five developmental stages are recognized.
   Step1 Sprouting new ideas and approaches from societal problems and establishing research development methods or methodology.
   Step2 Establishing a foundation based on new research methods and methodologies.
   Step3 Application to the various phenomena or cases of new techniques or methodologies.
   Step4 Evolution of seeds, verification of technology, bridge to industrialization.
   Step5 Verification of technology effects and safety, derivation of new basic

research issues.

(4) The process takes more than 15 to 20 years to develop.

(5) The process of expanding participants from researchers, industry, academia, government and society.

Therefore, in order to promote the emerging and interdisciplinary science and technology, the following points need to be realized.

- Research and development should not be conducted to fit the system, but support should be adjusted accordingly to the progress of the research and development.
- The merge of the following two items, which are, the merge of disciplines, and the merge of knowledge and social value creations needs to be realized.

It is outlined more specifically in the following four proposals.

The Four Proposals toward the Promotion of Emerging and Interdisciplinary Science and Technology

Proposal 1: A seamless program for societal issues.

Proposal 2: Establishing a "strategic manager", the driving force for emerging and interdisciplinary science and technology

Proposal 3: Forming a network of a wide variety of researchers in industry, academia, government and society, who specialize in emerging and interdisciplinary science and technology

Proposal 4: Forming an environment and organization where researchers, especially young researchers can challenge freely in emerging and interdisciplinary science and technology.

Up till now, the concern of the technological forecasts or road mappings were mainly (what) as in "What kind of research or technology should we invest in?" On the other hand, it is now (for what) as in "What is the purpose of considering the kind of societal issues we need to respond to and making them worthy?" Furthermore, in order to clarify the societal issues we should pursue, we need to urgently establish a platform for industry, academia, government and society, which would bind together the wisdom of society and expectation to science and technology.

It is also necessary to realize and combine the time axis with the contents of both the continuity of "societal issues" which indicate the total direction, and the flexibility of the “research areas” which are the promoting tools selected under them according to the development of the emerging and interdisciplinary science and technology.

## 105. Developing a Method for Strategic Proposals for Strategic Planning on Research & Development for Strengthening Global Industrial Competitiveness Creation and Development of 'Umbrella Industries' utilizing 'Element Industries' which Japan boasts【Executive summary in English】

The Center for Research and Development Strategy (CRDS) has introduced concepts of new industrial categories of "Umbrella Industry" and "Element Industry" and developed methods to formulate research and development strategies to strengthen global competitiveness of industries in a more elaborative manner.
We have defined the "Umbrella Industry" as an industry that produces a system to generate significant values not only in inter-industry relations but also in social and economic perspectives by building a large system of added values through combination of parts and materials as a system or combination of such hardware technologies and software technologies to demonstrate optimum functions as a total system and call a product produced by the umbrella industry as an "Umbrella System." On the other hand, we decided to call parts and materials that are incorporated into the umbrella system as components and highly independent software technologies as an "Element System" and defined the industry to produce such system as the "Element Industry."

The CRDS proposes not to follow the measures to comprehensively strengthen part and materials industries centering on part and material industries with strong global competitiveness that Japan boasts, but to seek a method for visualization of R&D strategies by targeting the umbrella industry, which is a high value-added industry, uncovering specific research and development issues that are necessary to realize it, introducing and promoting temporal axes to solve these issues. According to this method, we can formulate R&D strategies to induce science and technology innovation and open innovation in a systematic and generation-to-generation developmental manner both in the "CRDS Umbrella Industry" and the element industry to be induced by realizing it.
We have defined that the "CRDS umbrella industry" meets the following four criteria and created a "Bird'S Eye View of Industrial Technologies to Formulate R&D Strategies that Induce Science and Technology Innovation" with the "CRDS Umbrella Industry" created based on these criteria as a horizontal axis and the "Element Industry" as a vertical axis.

1. Oriented to solve global environmental problems

2. Science and technology innovation is required to create that industry
3. Social and economic values are significant and can make a great contribution to improving Japan's GDP
4. Japan is positioned in a globally superior position to create it with the potential and expectations from the world

The CRDS umbrella industry is divided mainly into two areas. One is a "New Industry Aiming to Create High-Added Values Based on the Element Industry with Strong International Competitiveness that Japan Boasts" and the other is an "Essential Industry as Living and Social Basis although the Relationship with International Competitiveness is Now Remote." In the industrial classification, the former is classified into energy industry, resource development industry, environmental industry, information and communication industry and transportation industry. In this area, 28 CRDS umbrella industries were created. The latter is classified into food industry, medical industry, construction industry and education industry. In this area, 9 CRDS umbrella industries were created.

## 106. The Medium-and-long-term Strategy for developing Regional Innovation System - Aiming at Autonomous Development of Regional-based Ecosystem –【Executive summary in English】

The creation of regional innovation has been positioned as an important policy issue both in the 3rd-term Science and Technology Basic Plan and the Innovation 25 in Japan. From May to June 2008, not only the "Regional Vitalization Strategy by Science and Technology" advocated by the Council for Science and Technology Policy, but also a series of strategies and proposals towards creation of regional innovation by the Education, Culture, Sports, Science and Technology, Ministry of Economy, Trade and Industry, etc. were determined and announced one after another.
In this strategic proposal, we aim at autonomous development of regional-based ecosystem with the "Formation of Regional-Based Ecosystem," which was recommended by the CRDS strategic proposal and a vision of the "Regional Vitalization Strategy by Science and Technology" advocated by the Council for Science and Technology Policy, as a basic concept. In the medium- and long-term strategies, we covered such issues as formation of Regional COE Platform with universities at the core and acceleration of regional innovation by introducing a future regional system from the region-led perspectives as important items to consider in the future.

(Vision)
Aiming at autonomous development of regional-based ecosystem, we realize a vital regional society and strengthen the overall competitiveness of Japan by forming the Regional COE Platform with regional universities at core basis of knowledge, promoting further decentralization of power and creating the region-led unique, distinctive and autonomous regional innovation through the introduction of regional system. The roles of the government are to support the "initial roll-out," accelerate regulatory reform and eventually promote regional development by self-reliant efforts of private and local public organizations based on the market principles, while keeping these strategies impossible to make by the private sector.

(Goal)
The goals are to build about 10 global bases which are internationally competitive and 30 community-based bases that respond to regional needs by 2020 as a rough target and promote the coordination between the networks of each basis. In addition, we promote regional vitalization through expansion of new industries and employment by

introducing a regional system composed of about 10 districts as a result of further promotion of decentralization of power, promoting voluntary restructuring and consolidation of universities eyeing on specialization of educational and research functions within each region and creating regional innovation led by local public organizations such as unique and distinctive regional innovation policies.

(Medium-term strategy)
To form the “Regional COE Platform” with national university corporations, which are regional “Bases of Knowledge,” at the core and establish a “Place” to create regional innovation (environment that people involved in universities/specialized vocational high schools/public testing and research institutes, private companies, core support organizations, chambers of commerce and industry/commerce and industry associations, local public organizations, etc. vitalized by inspiring each other). In order to form global bases with international competitiveness and community-based bases that respond to regional needs, the government should provide not conventional and stereotyped measures but intensive support that flexibly responds to regional characteristics and forms by respecting originality and diversity based on regional circumstances. In so doing, local public organizations should take the initiative in mobilizing people involved in universities, private companies, etc. and establishing a clear regional strategy and its roadmap that respond to region-specific circumstances, while the government should provide support based on the strategies.

(Long-term strategy)
Towards the creation of strategic and effective regional innovation, to develop a regional innovation system led by a regional government based on successful examples of other countries with similar population and industry scale such as Finland by introducing a regional system of wide-area local governments to be replaced by municipalities which are basic local governments based on the population of 200,000 to 300,000 people and prefectures. Furthermore, a regional government should support voluntary restructuring and consolidation of universities on their own will using advantages of scale eyeing on specialization of educational, research, social and regional contribution functions by expanding the university’s regional consortium that promote integration of national, public and private universities.

## 107. Establishment of the Global Innovation Ecosystem to Solve Global-scale Problems - Environment, Energy, Food and Water Challenges -【Executive summary in English】

Currently, there is growing crisis awareness for various global-scale problems that come from explosive increase in population and expansion of human activities. In particular, a lot of attention has been paid to global warming resulting from increase of greenhouse gasses in the air (carbon dioxide, methane, etc.). At the G8 Summit 2007 Heiligendamm, the Japanese government proposed "Cool Earth 50," insisting that there should be a new framework to eliminate greenhouse gasses by participation of the entire world beyond the Kyoto Protocol. This proposal was widely supported and the members of the G8 Summit agreed to seriously examine to at least halve greenhouse gas emissions throughout the world by 2050. In the G8 Hokkaido Toyako Summit to be held in 2008, the participants are expected to discuss about the next-term climate change framework agreement after 2013.

Increasing global-scale problems range from global warming to desertification and lack of water/foods in African and Asia, sudden rise and outbreak of emerging infections, skewed distribution and depletion of natural resources such as oil and rare metals, and widening and increasing visibility of disparity. With globalization of economic activities, companies must win intensifying international competition through global development of research and development, production and sales.

Under such background, every country around the world must tackle with these global-scale problems by capitalizing on each position and strengths and making concerted efforts. For this purpose, it is necessary to establish a global-scale innovation system, that is, Global Innovation Ecosystem (GIES), which allows global expansion of innovation systems of each country. The GIES is a concept proposed through collaboration among government, industry and academia and aims to solve global-scales problems and balance sustainable development by creating new social and economic values through competition and partnership between public and private sectors. This strategic proposal covers the following four global-scale problems as examples from the position of science and technology innovation and proposes solutions for 2050. Under the concept of GIES, we combine a "Shape of an Ideal Society" that we should realize and technologies that contribute to the realization as a package, and present research and development issues that we need to address and necessary political issues as "Methods of Attainment."

(1) Effective use of natural energy
(2) Environmentally low-load transportation system
(3) Supply of safe water
(4) Stable supply of safe food

## 108. Priorities for Realization of Science and Technology Innovation - Recommendation on Political Issues Requiring Immediate Response - 【Executive summary in English】

The Center for Research and Development Strategy (CRDS) has defined “Science And Technology Innovation” as “To Create Novel Social and Economic Values Based on Scientific and Technological Knowledge” and recommended that the realization of science and technology innovation should be a top-priority political issue in Japan. This strategic proposal extracted five factors of innovation that require urgent response and political issues of each factor as follows along with priorities of social visions towards the realization of science and technology innovation and proposed them as political issues that require urgent response.

1. Supply of risk money

   Persistent supply of funds (allocating a small portion of pension and postal savings to venture capitals and outsourcing the operation to a private specialized institution), appointment of specialists to government organizations, creation of angels as mentors, improvement and expansion of tax system for donations

2. Creation of innovation-oriented market and design of the system

   2.1 Design of innovation-oriented system

   Introduction of a mechanism to promote distribution of intellectual property rights, induction of innovation by using regulations, standardization of technologies eyeing global development, coordination between companies for global markets, implementation of projects to enhance trust in innovation

   2.2 Innovation-oriented public procurement

   Revision of a competitive bidding qualification system, improvement and expansion of SBIR (Small Business Innovation Research), building of functions that match emerging needs and seeds, reexamination of voluntary measures in Japan surpassing the WTO Government Procurement Agreement from perspectives of innovation, procurement strategy to promote innovation

3. Improvement of mobility of human resources, formation and strengthening of networks

   Improvement and expansion of incentives to promote mobility of human resources necessary for innovation (relaxation of conditions of application for incentive (or qualified) stock option, elimination of factors inhibiting mobility of human resources necessary for innovation (introduction of researchers of public research institutes to 401k Defined Contribution Plan), cultivation of entrepreneurship among students and faculty members at universities, research institutes, etc., formation and strengthening of networks, improvement of accepting foreigners and support system

4. Establishment of regional innovation ecosystem (RIES) from new perspectives.

Securing of critical mass for creation of innovation, promotion of "place establishment" in unit of state to be introduced as social innovation towards promotion of decentralization of power, promotion of integration and restructuring of national, public and private universities/public research institutes within the state and promotion of support measures such as setting a special quota for subsidies of operational expenses towards establishment of regional COE

5. Vitalization of "place" of innovation by "creation of knowledge"

Formation of COE that leads the world innovation, promotion of high-target and high-risk research with strong social impact, utilization of pooled facilities and equipment to establish innovative research environment, promotion of reform of universities responsible for "creation of knowledge," vitalization of "place" by private companies, contribution to creating "place" of global innovation

## 109. Proposal for Realization of Science and Technology Innovation - Overview of National Innovation Ecosystems and Related Political Issues -【Executive summary in English】

This proposal recommends the roles that Japan should play and the measures in order to improve the environment that enables science and technology innovation.

The Center for Research and Development Strategy (CRDS) has defined science and technology innovation as "To Create Novel Social and Economic Values Based on Scientific and Technological Knowledge" and concluded that the innovation that Japan should address and promote as a political issue is science and technology innovation. Science and technology innovation is a process of high uncertainty that can be achieved after overcoming various trials and errors and ingenious attempts and it does not occur by research and development that pursues only short-term achievement alone.
Japan's roles are to improve the environment in which science and technology innovation is easily induced and to connect the achievement of research investment in accordance with the basic scientific and technological plan with creation of innovation. Based on this claim, this proposal first surveyed the environment in which science and technology innovation is easily induced and, based on this, described political agenda and recommendations to respond to them.

1. Overview of science and technology innovation

In order for scientific knowledge and technological seeds to be connected with science and technology innovation, various "factors" need to function and coordinate with each other in the process of innovation.
We summarized factors that contribute to innovation in the five factor groups as follows and presented a bird's-eye view of these groups in a figure centering on three steps of innovation ("Entrance," "Place" and "Exit") and three factors which are indispensable in each step of innovation ("Human Resources," "Funds" and "Knowledge, Wisdom and Insight").

(1) "Creation of Knowledge"
(2) "Mobility of Human Resources, Network"
(3) "Supply of Risk Money"
(4) "Creation of Innovation-Oriented Market, Design of the System"
(5) "Regional Innovation"

2. Political issues and proposals for science and technology innovation

In order to make sure that these factors of innovation effectively function, coordinate with each other and realize science and technology innovation, various innovation-related organizations need to get actively involved in the realization and operation of these factors. Here, we classified the related organizations into the following three groups and summarized political issues and proposals for these organizations in relation to the factor groups that contribute to science and technology innovation.

(1) Governmental organizations (policymaking organizations, related government offices and ministries, fund allocation organizations, etc.)

(2) Research implementing organizations (universities and public research institutes, scientific organizations, etc.)

(3) Private companies, etc. (leading companies, R&D-oriented small companies, venture companies, R&D-oriented NPOs, venture capital firms, angel funds, etc.)

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