MOONSHOT

RESEARCH & DEVELOPMENT PROGRAM

2024.Jun

Moonshot R&D Program
Overview

Here begins our new MIRAI

MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM

Here begins our new MIRAI.

Let's repaint the future

to be brighter, more vibrant, more beautiful.

Our planet and its people now face many serious challenges,

so let's gather our collective strength.

We can overcome old limits

by converging global knowledge,

and break convention with radical innovation.

This is our new MIRAI.

A future inspired by science, but shaped by human spirit.

Don't think it's impossible. Don't be afraid to fail.

Don't feel constrained by prior expectations.

Let's paint the future to be full of smiling faces,

by our hands as we live courageously today.

Here begins our new MIRAI.

10 GOALS

To tackle important social issues including our shrinking and aging societies, global climate change and extreme natural disasters, the Moonshot R&D Program is pursuing disruptive innovations in Japan and promoting challenging R&D based on revolutionary concepts. The program's research aims to achieve ten ambitious Moonshot Goals.

1 Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050.
HAGITA Norihiro Chair and Professor, Art Science Department, Osaka University of Arts

2 Realization of ultra-early disease prediction and intervention by 2050.
SOBUE Gen Chairperson, Aichi Medical University

3 Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.
FUKUDA Toshio Visiting Professor, Institute of Innovation for Future Society, Nagoya University

4 Realization of sustainable resource circulation to recover the global environment by 2050.
YAMAJI Kenji President, Research Institute of Innovative Technology for the Earth (RITE)

5 Creation of industry that enables sustainable global food supply by exploiting unused biological resources by 2050.
CHIBA Kazuhiro President, Tokyo University of Agriculture and Technology

6 Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.
KITAGAWA Masahiro Director, Center for Quantum Information and Quantum Biology, Osaka University

7 Realization of sustainable care systems to overcome major diseases by 2040, for enjoying one's life with relief and release from health concerns until 100 years old
HIRANO Toshio Professor Emeritus, Osaka University, President, Osaka International Cancer Treatment Foundation

8 Realization of a society safe from the threat of extreme winds and rains by controlling and modifying the weather by 2050.
MIYOSHI Takemasa Team Leader, Center for Computational Science, Data Assimilation Research Team, RIKEN

9 Realization of a mentally healthy and dynamic society by increasing peace of mind and vitality by 2050.
KUMAGAI Seiji Professor, Institute for the Future of Human Society, Kyoto University

10 Realization of a dynamic society in harmony with the global environment and free from resource constraints, through diverse applications of fusion energy, by 2050.
YOSHIDA Zensho Director General, National Institute for Fusion Science, National Institutes of Natural Sciences

1

Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050.

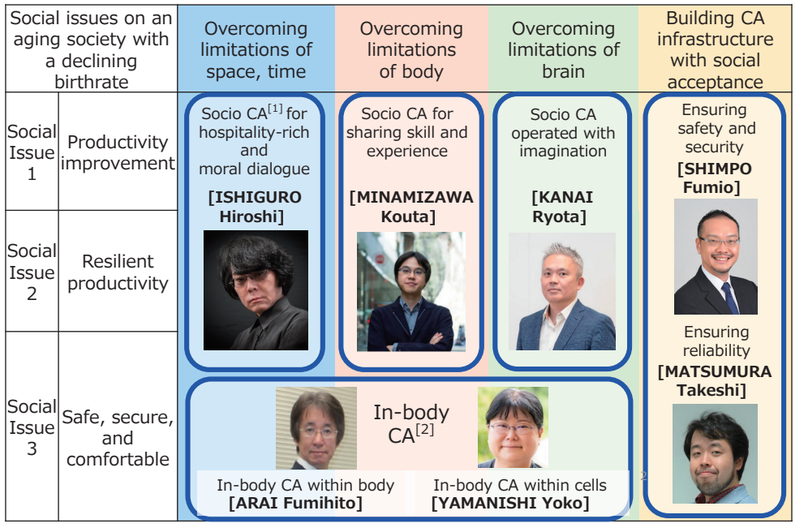
Program Director (PD) **HAGITA Norihiro** Chair and Professor, Art Science Department, Osaka University of Arts

Outline

To overcome the challenges of a declining birthrate, aging population and associated labor shortage, the key is to allow people with various backgrounds and values – such as the elderly and those with responsibilities for nursing and childcare – to actively participate in society.
Our R&D program solves the three social issues of "increasing productivity", "maintaining strong productivity against disasters and infectious diseases", and "safe, secure, and comfortable daily life" by developing core technologies related to cyborgs and avatars, called 'Cybernetic Avatars (CAs)'. The CAs allow expansion of human physical, cognitive and perceptual capabilities, to realize a society in which "human beings can be free from the limitations of body, brain, space, and time" by 2050, while taking into account socially accepted ideas.

Message from PD

To achieve the moonshot goal 1, we will promote research and development of CAs that enable people with various backgrounds and values to expand their physical, cognitive, and perceptual capabilities to the top level. In addition, we will realize a CA that can be deployed anywhere in society to enable people to perform various activities by remote control, as well as the CA infrastructure necessary for its operation.
Based on this infrastructure, we plan to provide "Socio CAs", which provide services to individuals and groups, and "In-body CAs", which remotely watch over living organisms and cells, to solve three social issues: "increasing productivity", "maintaining strong productivity against disasters and infectious diseases", and "safe, secure, and comfortable daily life".
Furthermore, in order to clarify technical and institutional issues common to different CAs through a cross-sectional examination of the R&D results of "Socio CAs" and "In-body CAs", and to create a forum for proposals and the collection of opinions from citizens for the resolution of technical and institutional issues in Japan and abroad, we will promote "R&D on social acceptance infrastructure" to ensure safety, security, and reliability and increase social acceptance.



[1]Socio CA: CA that provides services to individuals and groups
[2]In-body CA: CA that remotely watches over living organisms and cells

R&D Projects

The Realization of an Avatar-Symbiotic Society where Everyone can Perform Active Roles without Constraint

Project Manager	**ISHIGURO Hiroshi** Professor, Graduate School of Engineering Science, Osaka University
Outline	This project aims to realize an avatar-symbiotic society in which CAs allow everyone to perform active social roles without constraint. Through the teleoperation of multiple CAs that can fully transmit the user's actions, intentions, and reactions in scenarios which feature hospitality-rich dialogue, the user will be able to take part in various social activities (work, education, medical care, daily life, etc.). By 2050, our lifestyles will have dramatically changed. We will have greater freedom in our choice of location and how we spend our time, and technological advances will have enhanced our abilities. Our goal is to develop and implement avatar-symbiosis within a balanced society.

Cybernetic Avatar Technology and Social System Design for Harmonious Co-experience and Collective Ability

Project Manager	**MINAMIZAWA Kouta** Professor, Graduate School of Media Design, Keio University
Outline	This project aims to develop cybernetic avatar technologies that allow people to take full advantage of their abilities and share their variety of skills and experiences with many other people. Taking into account the social and ethical issues involved in the mutual utilization of physical skills and experiences, we will design a system that fits well with humans and society. By 2050 the inter-distribution of skills and experiences will allow people to link together and produce co-creations, and help realize a society in which everyone can freely engage in physical activities and challenges through cybernetic avatars.

Liberation from Biological Limitations via Physical, Cognitive and Perceptual Augmentation

Project Manager	**KANAI Ryota** Director, Advanced Telecommunications Research Institute International (ATR)
Outline	This project aims to develop cybernetic avatars that can be controlled via intention. This intention will be estimated from brain activities and information observed on the surface of the human body and through interactions. We will integrate intention estimation methods using AI technologies, and enhance the functionality of cybernetic avatars controlled by brain machine interfaces (BMI) while considering ethical implications. By 2050, we will create the ultimate BMI-cybernetic avatars that can be freely operated by human intention.

Structuring Spatiotemporal Environmental Information in the Body Using In-body Cybernetic Avatars.

Project Manager	**ARAI Fumihito** Professor, Graduate School of Engineering, The University of Tokyo
Outline	This project aims to develop an in vivo Cybernetic Avatar (in vivo CA) that can visualize the state of health in the body. We will structure spatio-temporal environmental information in the body by distributing and coordinating multiple types of millimeter-, micro-, and nanoscale in vivo CAs to realize health monitoring and ultraminimally invasive diagnostics. By 2050, it will be useful for health maintenance, diagnosis, and disease prevention, and will be used by people in their daily lives, thereby contributing to a society of health and longevity.

Realization of a Society Watched over by Remote Control of Intracellular Cybernetic Avatar

Project Manager	**YAMANISHI Yoko** Professor, Faculty of Engineering, Kyushu University
Outline	This project aims to develop intracellular Cybernetic Avatars that extend the body's own immune capabilities. By remotely controlling multiple intracellular Cybernetic Avatars, doctors, and specialists will be able to patrol the body, inspect the malignant state of disease-causing cells, remove them if necessary, and keep the body in good condition at all times. By 2050 we aim to realize a safe and secure daily life and an increase in healthy life expectancy watched over by intracellular Cybernetic Avatars.

Realization of a Society that can Use Cybernetic Avatars Safely and Securely

Project Manager	**SHIMPO Fumio** Professor, Faculty of Policy Management, Keio University
Outline	This project aims to create core technologies on CA Teleoperator authentication, CA authentication and CA notarization that proves and certifies that the teleoperator can publicly use the CA under the law to build a CA infrastructure ensuring safe and security. It does research E^3LSI(Ethical, Economic, Environmental, Legal, and Social Issues) to be tackled for realization of CA lifestyle, and create opportunities for proposals and discussions both domestically and internationally. We aim to develop a new dimension of jurisprudence such as AI, robotics, and avatar law, by 2050.

Reliability-ensuring Cybernetic Avatar Infrastructure Allowing Interactive Teleoperation

Project Manager	**MATSUMURA Takeshi** Director, Wireless Systems Laboratory, Wireless Networks Research Center, Network Research Institute, National Institute of Information and Communications Technology
Outline	This project aims to develop a reliability-ensuring infrastructure that enables remote control of various CAs even when unstable communication conditions such as jitter (time lag and fluctuation of signals), latency, and communication failures occur. To this end, it develops area optimization technology for wireless sections and network optimization technology including wired sections to maintain interactive connections between operators and multiple CAs to the maximum extent. We will build a reliability-assuring infrastructure that will enable CA remote control underwater, undersea, and in space by 2050.

Program Director
HAGITA Norihiro

https://www.jst.go.jp/moonshot/en/program/goal1/

Japan Science and Technology Agency

2

Realization of ultra-early disease prediction and intervention by 2050.

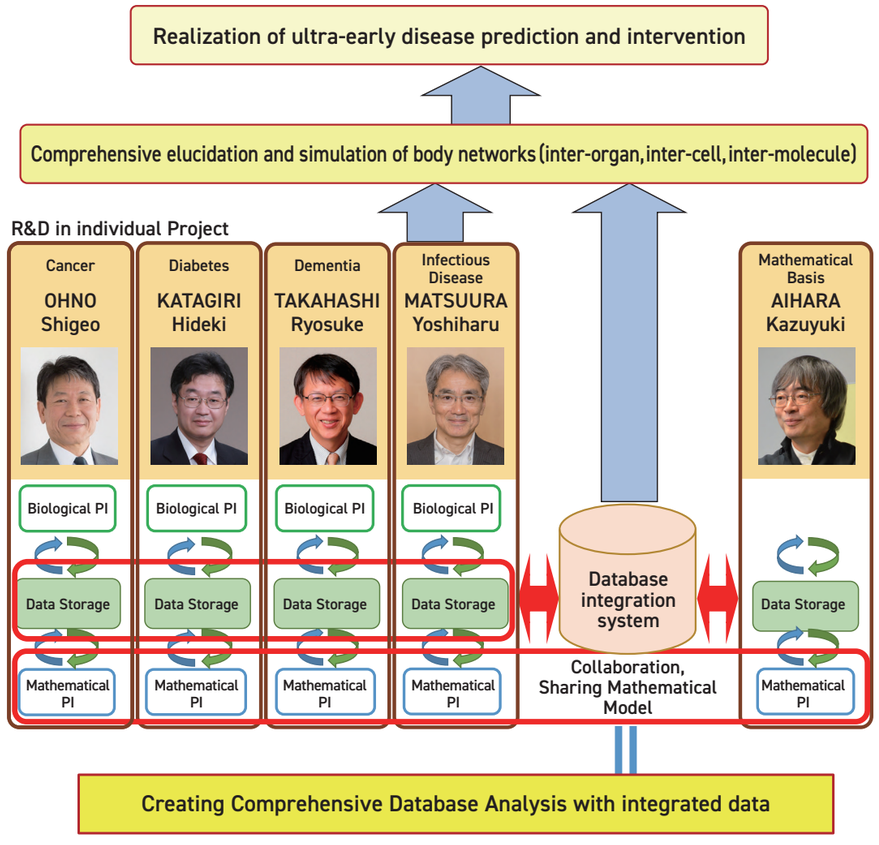
Program Director (PD) **SOBUE Gen** Chairperson, Aichi Medical University

Outline

To ensure that our aging population has continued health and high quality of life, we need a new style of ultra-early disease prediction and intervention that supersedes today's conventional approach of treatment only after detection of symptoms.
To achieve this Moonshot Goal and realize ultra-early disease prediction and intervention we will promote R&D on technologies related to disease observation, manipulation, measurement, analysis, database creation and more. By integrating these technologies, we will advance our understanding of the comprehensive network connecting human organs.

Message from PD

The states of chronic diseases such as diabetes and dementia are linked to the breakdown of inter-organ networks. The key to our Moonshot Goal is establishing a method to foresee this breakdown and help at-risk individuals convert back from a pre-symptomatic state to a healthy one. Our R&D projects will contribute to our understanding of the comprehensive inter-organ network, building a database describing the network state, and developing a simulation system predicting unstable health utilizing mathematical models.



PI=Principal Investigator

R&D Projects

Comprehensive Mathematical Understanding of the Complex Control System between Organs and Challenge for Ultra-Early Precision Medicine

Project Manager: **AIHARA Kazuyuki**
University Professor / Professor Emeritus, The University of Tokyo

Outline: This project will establish integrated research between mathematical studies with mathematical data analysis and mathematical modeling analysis, and experimental studies on interaction and control between organs. This project aims to realize a society equipped with ultra-early disease prevention systems by 2050 through comprehensively understanding the inter-organ network as the complex control system between organs and applying it to ultra-early precision medicine.

Challenge toward the Control of Intractable Cancer through Understanding of Molecular, Cellular, and Interorgan Networks

Project Manager: **OHNO Shigeo**
Special Contract Professor, Graduate School of Medicine, Juntendo University

Outline: This project aims to unravel the mechanism of onset and malignant transformation of intractable cancers such as pancreatic cancer by employing cell biology, imaging technology, and mathematical and AI technology in an integrated manner.
By doing so we aim to realize a society allowing us to predict and prevent the onset of intractable cancers by 2050.

Challenge for Eradication of Diabetes and Comorbidities through Understanding and Manipulating Homeostatic Systems

Project Manager: **KATAGIRI Hideki**
Professor, Graduate School of Medicine, Tohoku University

Outline: This project aims to comprehensively elucidate the inter-organ communication systems underlying dynamic homeostasis of metabolism and circulation, taking advantage of original technologies, AI approaches and mathematical analyses. Furthermore, through understanding and manipulating the homeostatic systems, we will implement strategies which enable us to easily detect subjects in pre-symptomatic states of diabetes and comorbidities and to prevent the developments of these diseases by 2050.

Towards Overcoming Disorders Linked to Dementia based on a Comprehensive Understanding of Multiorgan Network

Project Manager: **TAKAHASHI Ryosuke**
Specially Appointed Professor, Graduate School of Medicine, Kyoto University

Outline: This project aims to elucidate the interdependent multiorgan network and its breakdown at the molecular, cellular, and individual levels, focusing not only on the brain but also on the relationship between the whole body and the brain. Furthermore, we will achieve a comprehensive understanding of multiorgan network through AI and a mathematical approach. Based on this, we will develop methods for predicting disorders linked to dementia at an early stage before onset and realize preemptive medicine by using an innovative method for disease prevention by controlling the multiorgan network by 2050.

Understanding and Control of Virus-Human Interaction Networks

Project Manager: **MATSUURA Yoshiharu**
Specially Appointed Professor, Research Institute for Microbial Diseases, Osaka University

Outline: This project aims to analyze the interaction network between the virus and the human body in viral infections and classify/categorize its patterns to identify vulnerabilities in the human body's network. This will enable us to preemptively prepare effective diagnostic, preventive and therapeutic measures against even unknown viral infections, and thereby realize a society free from the threat of viral infections by 2050.

Program Director
SOBUE Gen

https://www.jst.go.jp/moonshot/en/program/goal2/

3

Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.

Program Director (PD) **FUKUDA Toshio** Visiting Professor, Institutes of Innovation for Future Society, Nagoya University

Outline

Considering Japan's declining birthrate and aging population, it is important that robots can be used in all aspects of society - such as working in dangerous or understaffed sites, developing human frontiers, and supporting our everyday lives. For that purpose, robots must be able to learn and act on their own through the co-evolution of AI and robots. Our R&D aims to realize AI robots with advanced bodies and self-developed AI learning.

Message from PD

Our R&D aims to achieve the following three outcomes by 2050:

(1)AI robots that autonomously make judgements and act in environments where it is difficult for humans to act.

(2)An automated AI robot system that aims to discover impactful scientific principles and solutions, by thinking and acting in the field of natural science.

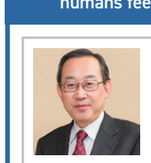
(3)AI robots that humans feel comfortable with, have physical abilities equivalent to or greater than humans, and grow in harmony with human life.

The following two concepts are core to our work:

(1)Coevolution: AI technology and robot technology cooperate to improve their own performance.

(2)Self-organization: AI technology and robot technology self-modify their own knowledge and functions to adapt to their environment.

Development of AI robots that humans feel comfortable with



SUGANO Shigeki

Smart Robot that is Close to One Person for a Lifetime

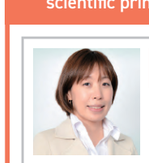
HIRATA Yasuhisa

Adaptable AI-enabled Robots to Create a Vibrant Society

SHIMODA Shingo

Awareness AI Robot System for Leading Proactive Behavior Improvement

Development of an automated AI robot system that aims to discover impactful scientific principles and solutions



HARADA Kanako

Co-evolution of Human and AI-Robots to Expand Science Frontiers

USHIKU Yoshitaka

AI & Robots that Harmonize with Humans to Create Knowledge and Cross Its Borders

Development of AI robots that autonomously make judgements and act in difficult environments

NAGATANI Keiji

Collaborative AI robots for adaptation of diverse environments and innovation of infrastructure construction

KUNII Yasuharu

Intelligent Multi Agents for Exploration and Settlement in Unknown and Unexplored Areas

YOSHIDA Kazuya

Self- Evolving AI Robot System for Lunar Exploration and Human Outpost Construction

R&D Projects

Smart Robot that is Close to One Person for a Lifetime

Project Manager: **SUGANO Shigeki**
Professor, Faculty of Science and Engineering, Waseda University

Outline: This project aims to establish robot evolution technology that combines flexible machine hardware and unique AI that can understand many kinds of tasks. Our final goal is to build a human-robot symbiotic society by introducing a general-purpose AI robot that can work with people not only in housework and customer service but also in welfare and medical fields where human resources will be in short supply by 2050.

Collaborative AI robots for adaptation of diverse environments and innovation of infrastructure construction

Project Manager: **NAGATANI Keiji**
Project Professor, School of Engineering, The University of Tokyo

Outline: This project aims to develop collaborative AI robots that respond to various situations flexibly and perform given tasks in challenging environments such as disaster sites. By 2050 these collaborative AI robots will, on behalf of humans, conduct emergency response missions following natural disasters. This technology will also be useful for the construction and maintenance of ground infrastructure.

Co-evolution of Human and AI-Robots to Expand Science Frontiers

Project Manager: **HARADA Kanako**
Associate Professor, Graduate School of Medicine, Graduate School of Engineering, The University of Tokyo

Outline: This project aims to develop AI-robots that conduct scientific experiments in challenging environments (e.g. in a hazardous atmosphere, or in a micro-scale setup), while interacting with scientists as their peers. AI robots and scientists will have freer interactions, and will work with unfamiliar objects and environments through trial-and-error together. By 2050 AI-robots will discover their own principles and solutions in the science fields.

Adaptable AI-enabled Robots to Create a Vibrant Society

Project Manager: **HIRATA Yasuhisa**
Professor, Graduate School of Engineering, Tohoku University

Outline: This project aims to create a collective of adaptable AI-enabled robots available at a variety of places. Each robot will be usable by anyone at any time, and will adjust its form and functions according to the individual user to provide optimal assistance and services. By 2050 the co-existence and co-evolution of a wide variety of robots and people will create a vibrant society in which all people can participate.

AI & Robots that Harmonize with Humans to Create Knowledge and Cross Its Borders

Project Manager: **USHIKU Yoshitaka**
Vice President for Research, OMRON SINIC X Corporation

Outline: Deductive reasoning is necessary for paradigm-sustaining innovation. For paradigm disruption, abductive reasoning and knowledge creation have a key role. Transilience is also required for transdisciplinary paradigm disruption. This project aims to realize an AI that first understands and reviews such researchers' ideas based on their research articles. We will then develop AI robots that can conduct research in a loop of assertion, experiment, analysis, and description while interacting with human researchers by 2030. We aim for a world where humans and AI are in harmony and produce Nobel Prize-level research by 2050.

Intelligent Multi Agents for Exploration and Settlement in Unknown and Unexplored Areas

Project Manager: **KUNII Yasuharu**
Professor, Faculty of Science and Engineering, Chuo University

Outline: Our project aims to explore and construct a habitable environment in the unknown environments of lunar lava tubes using small swarm robots. We tackle the research and development of both software and hardware aspects of the necessary functions for achieving our goals, including the ability for small exploration robots to gather in swarms and perform autonomous behaviors, functions for robots and systems to evolve, robot locomotion mechanisms to traverse challenging environments, and intelligence through shared AI functions. Through these efforts, we aim to create a future where humans can live inside lunar lava tubes by 2050.

Awareness AI Robot System for Leading Proactive Behavior Improvement

Project Manager: **SHIMODA Shingo**
Unit Leader, RIKEN Center of Brain Science

Outline: This project aims to develop Awareness AI to support our proactive lives based on our individual requirements, social roles, and hopes for the future. In the modern society where values among the people is diverged, people must become aware of what to do or what they want to do by ourselves in daily life. Awareness AI assists this decision via the appropriate stimulation of our unconscious thought processes. By 2050, we create a society where everybody can live proactively according to their best-fit social role and hopes for the future through the awareness AI support.

Self- Evolving AI Robot System for Lunar Exploration and Human Outpost Construction

Project Manager: **YOSHIDA Kazuya**
Professor, Graduate School of Engineering, Tohoku University

Outline: This project aims to develop a self-evolving AI robot system for lunar exploration and human outpost construction. Core technologies will be established that effectively utilize the components deployed to the moon, enabling modules to be reconfigured according to lunar conditions and mission tasks. By 2050, exploration and resource utilization on the moon will be promoted to realize sustainable outposts for human presence in space.

Program Director

FUKUDA Toshio

https://www.jst.go.jp/moonshot/en/program/goal3/

4

Realization of sustainable resource circulation to recover the global environment by 2050.

Program Director (PD) **YAMAJI Kenji** President, Research Institute of Innovative Technology for the Earth (RITE)

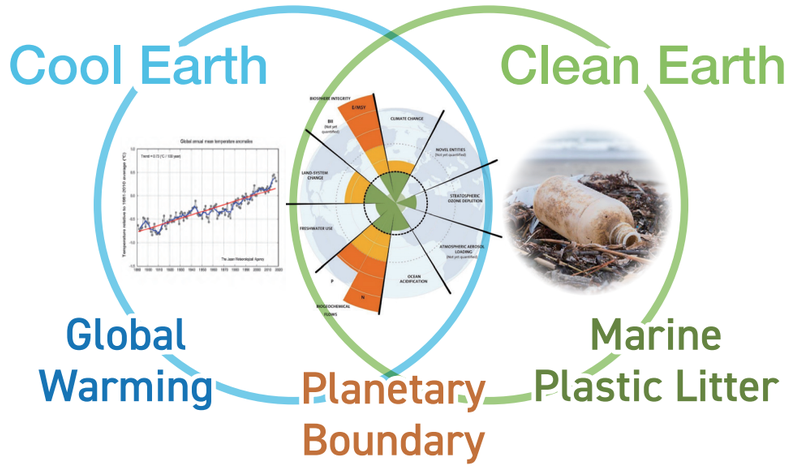
Outline

We must take measures to prevent the circulation of substances that cause global environmental problems. These include greenhouse gases (GHGs) responsible for global warming, nitrogen compounds in a high-risk state that exceed the threshold determined by the planetary boundary concept [*1], and marine plastic litter that disturbs marine ecosystems and can affect humans through the food chain.
To restore the global environment, this R&D program aims to contribute to solving the global warming problem (Cool Earth) and the environmental pollution problem (Clean Earth) while accounting for continued industrial and consumer activity. Under this program, NEDO is engaged in ambitious R&D activities to realize a new form of resource circulation that reduces environmental pollutants such as GHGs, nitrogen compounds, and marine plastic litter.

*1:Under this concept, thresholds have been established in nine areas of the global environment to ensure the sustainable development of human society. Exceeding these thresholds will cause irreversible changes to the natural resources upon which humans depend.

Message from PD

Moonshot R&D is characterized by its more ambitious and unconventional approach. For GHGs, the program is targeting an innovative technology known as Direct Air Capture (DAC), which directly captures CO_2 that has already been released into the atmosphere and utilizes it effectively. For nitrogen, we aim to detoxify nitrogen compounds discharged into the environment and convert them into valuable materials. As for marine plastic litter, a growing concern in recent years, we aim to design degradation initiation switches for biodegradable plastics that are functional yet safe for the environment.



R&D Projects

Development of Highly Efficient Direct Air Capture (DAC) and Carbon Recycling Technologies

Project Manager	**KODAMA Akio** Professor, Institute for Frontier Science Initiative, Kanazawa University
Outline	-Development of innovative amine-loaded CO_2 solid sorbent -CO_2 capture and enrichment process using less energy than conventional technologies -Membrane reactor for highly efficient and energy-saving synthesis of liquid hydrocarbon fuels using inorganic membranes

Integrated Electrochemical Systems for Scalable CO_2 Conversion to Chemical Feedstocks

Project Manager	**SUGIYAMA Masakazu** Professor, Research Center for Advanced Science and Technology, The University of Tokyo
Outline	-CO_2 enrichment process at medium and low temperatures by physical absorption/desorption and electrochemistry -Creation of a system for CO_2 enrichment and reduction to chemical feed stocks by electro-chemical processes using renewable electricity -Flexible system that allows for small-scale distributed deployment

Research and Development Toward Saving Energy for Direct Air Capture With Available Cold Energy

Project Manager	**NORINAGA Koyo** Professor, Institutes of Innovation for Future Society, Director of Research Center for Net Zero Carbon Society, Nagoya University
Outline	-Direct capture of atmospheric CO_2 by employing unused cold energy from liquefied natural gas (LNG) -Pressure swing recovery of CO_2 by the CO_2 sublimation while operating both absorber and desorber at room temperature -Output high-purity and pressurized CO_2 ready for storage and utilization process

Development of Global CO_2 Recycling Technology Towards “Beyond-Zero” Emissions

Project Manager	**FUJIKAWA Shigenori** Distinguished Professor, International Institute for Carbon-Neutral Energy Research, Director of Research Center for Negative Emission Technology, Kyushu University
Outline	-Development of CO_2 capture unit using innovative separation nano-membranes with unparalleled CO_2 permeability -Development of conversion unit that converts CO_2 into carbon fuel with high efficiency -Scalable system for use in small-sized homes and medium-sized buildings

C^4S[*2] Research and Development Project

Project Manager	**NOGUCHI Takafumi** Professor, Graduate School of Engineering, The University of Tokyo
Outline	-Capturing atmospheric CO_2 with concrete waste -Permanent resource circulation by regenerating calcium carbonate concrete (CCC) from concrete waste after CO_2 capture -Contributing to sustainable circulation of calcium resources as well as CO_2 *2: Calcium Carbonate Circulation System for Construction

Advanced Enhanced Rock Weathering (A-ERW) Technology Actively Combined With Site Characteristics

Project Manager	**NAKAGAKI Takao** Professor, School of Creative Science and Engineering, Faculty of Science and Engineering, Waseda University
Outline	-Accelerating artificial weathering and CO_2 mineralization utilizing characteristics of Japanese rocks and application sites -Evaluating pretreatment energy, modelling CO_2 absorption rate and sequestration, and predicting co-benefits for industrial and agricultural applications -Consolidating information database of accurate carbon accounting toward international standards

Feasibility Study of Enhanced Mineralization Based on LCA/TEA Platform

Project Manager	**MORIMOTO Shinichirou** Team Leader, Environmental and Social Impact Assessment Team, Global Zero Emission Research Center, National Institute of Advanced Industrial Science and Technology (AIST)
Outline	-Accounting the amount of CO_2 fixation of enhanced weathering through a mafic rocks database and CO_2 fixation measurement technology -Development of LCA/TEA assessment tool for total system design by realization of faster carbonation technology and optimizing utilization methods of mafic rocks to enhance plant growth

Redesign of Macroalgae for Highly Efficient CO_2 Fixation by Functional Modifications and Their Product Generation

Project Manager	**UEDA Mitsuyoshi** Professor, Special Appointed Professor, IAC (Office of Institutional Advancement and Communication) , Kyoto University
Outline	-Breeding of macroalgae by redesign for highly efficient CO_2 fixation including genome editing technology -Enlargement of marine field for macroalgae -Production of functional bio-products from macroalgae

4

Development of Next-Generation CO_2-Fixing Plant Through the Gene Optimization, Distant Hybrid, and Microbial Symbiosis

Project Manager: **MITSUDA Nobutaka**
Deputy Director, Bioproduction Research Institute/Global Zero Emission Research Center, National Institute of Advanced Industrial Science and Technology (AIST)

Outline
-Development of gene optimization for more accumulation of cell walls
-Development of distant hybrid plant generation system for more biomass production
-Finding symbiotic micro-organisms accelerating plant biomass production

Agrobiotechnological Direct Air Capture Towards Carbon Circulation Society

Project Manager: **YANO Masahiro**
Senior Executive Researcher, National Agriculture and Food Research Organization (NARO)

Outline
-Design and evaluation of "super DAC crop" by modifications and optimization of allelic combinations of genes related to CO_2 absorption/fixation and biomass production capacity
-Development of techniques to assess the decomposition and carbon dynamics of crop residues in soil
-Economic value and life cycle assessments of carbon circulation from crop production to recovery and utilization of valuables

Mitigation of Greenhouse Gas Emissions From Agricultural Lands by Optimizing Nitrogen and Carbon Cycles

Project Manager: **MINAMISAWA Kiwamu**
Specially Appointed Professor, Graduate School of Life Sciences, Tohoku University

Outline
-Focusing on agricultural lands as major sources of nitrous oxide and methane emissions
-Activation of N and C cycling in soil micro-organisms induces 80% reduction of nitrous oxide and methane emissions
-Design of soil microbial community could provide the establishment and functional expression of inoculated microorganisms

Innovative Circular Technologies for Harmful Nitrogen Compounds/ To Solve Planetary Boundary Issues

Project Manager: **KAWAMOTO Tohru**
Prime Senior Researcher, Nanoparticle Functional Design Group, Nanomaterials Research Institute, National Institute of Advanced Industrial Science and Technology (AIST)

Outline
-Development of technology to transform nitrogen oxides in exhaust gas into ammonia, a useful material
-Conversion and recovery of ammonia from toxic nitrogen compounds in wastewater

Development of Recovery and Removal Techniques of Dilute Reactive Nitrogen to Realize Nitrogen Circulating Society

Project Manager: **WAKIHARA Toru**
Professor, School of Engineering, The University of Tokyo

Outline
-Development of selective catalytic reduction (SCR) systems with both high selectivity and activity/durability by realizing precise control of zeolite structure and composition
-Development of absorbents for selective recovery and concentration of extremely low- concentration ammonia

Development of Multi-Lock Biopolymers Degradable in Ocean From Non-Food Biomasses

Project Manager: **ITO Kohzo**
Professor, Graduate School of Frontier Sciences, The University of Tokyo

Outline
-Breaking through trade-off between polymer degradability and dulability /toughness
-Multi-lock mechanism*3 provides high durability during use and on-demand degradation when accidentally released into ocean-Produced from non-food biomasses
*3: A mechanism that requires multiple stimuli such as light, heat, oxygen, water, enzymes, microorganisms, and catalysts at the same time for degradation

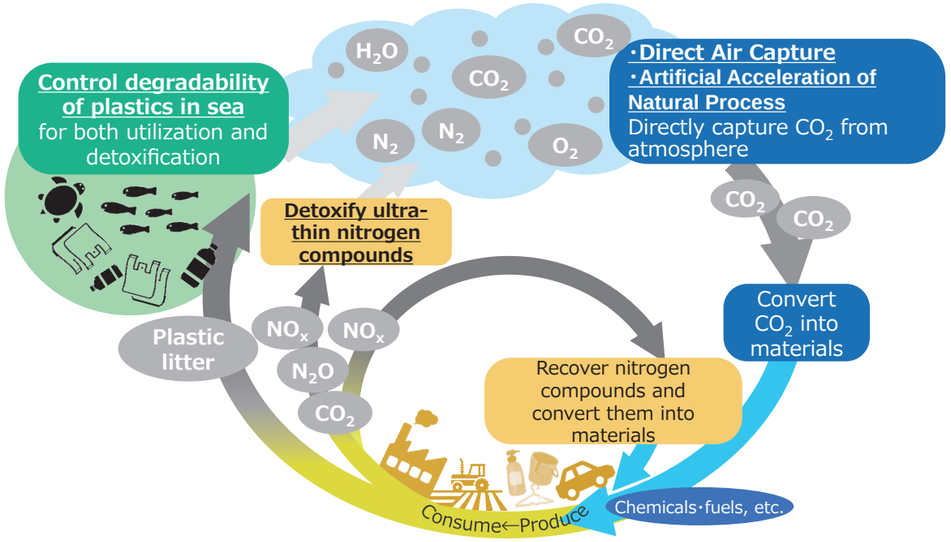
Research and Development of Marine Biodegradable Plastics With Degradation Initiation Switch Function

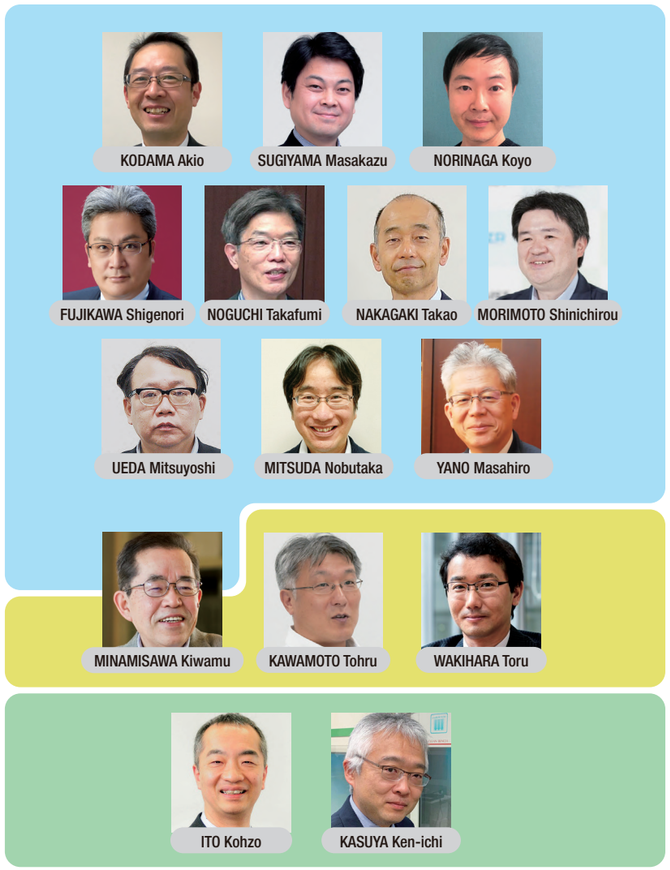
Project Manager: **KASUYA Ken-ichi**
Professor, Division of Molecular Science, Faculty of Science and Technology, Gunma University

Outline
-Development of technology to control timing and speed of degradation
-Marine biodegradability (90% in 6 months in seawater at 30°C) verified in ocean
-Creation of marine biodegradable polymers based on biomass and CO_2

NEDO New Energy and Industrial Technology Development Organization

Moonshot Goal 4 Cool Earth & Clean Earth





https://www.nedo.go.jp/english/news/ZZCA_100007.html

Program Director
YAMAJI Kenji

5

Creation of the industry that enables sustainable global food supply by exploiting unused biological resources by 2050.

Program Director (PD) **CHIBA Kazuhiro** President, Tokyo University of Agriculture and Technology

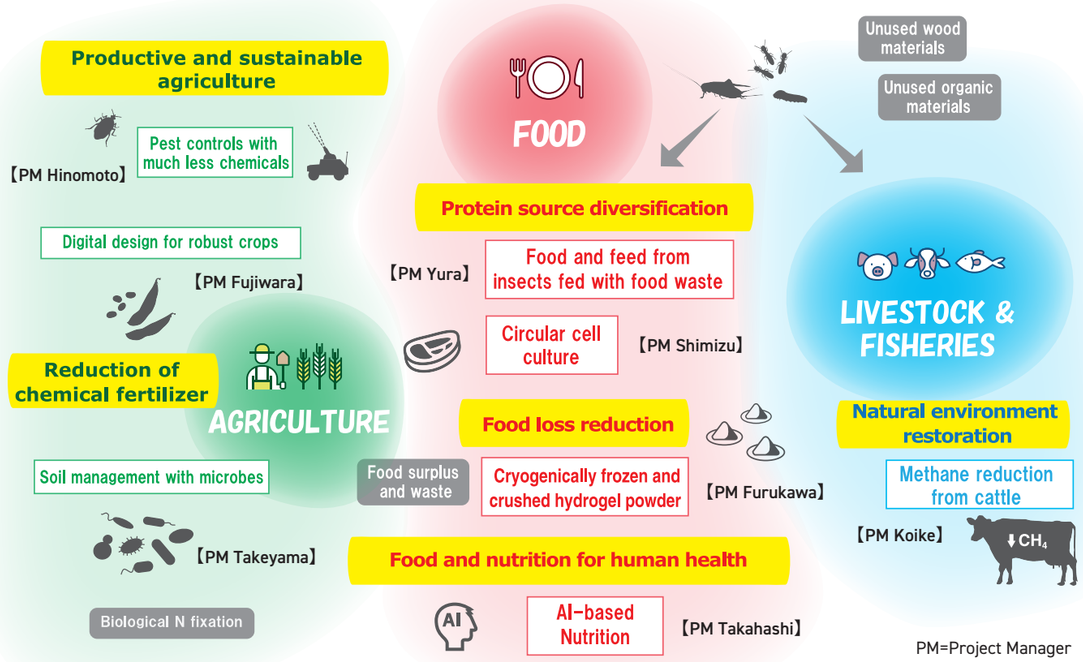
Outline

The global demand for food is estimated to increase 70% by 2050. Since excessive focus on production efficiency would hamper the cyclical function of the earth, it is essential to establish a food production system friendly to the global environment while increasing the food supply. Moonshot Goal 5 aims to address the issue with eight R&D projects, which are promoted by the Bio-oriented Technology Research Advancement Institution.

Message from PD

With the formation of agrarian societies, humankind has acquired a stable method of sustainable food supply. However, with the dramatic expansion of human activities in recent years, the sustainable supply of food, which is an inseparable part of human existence, has fallen into a situation where there is no longer any prospect for the immediate future. Overcoming this difficulty is not only a great responsibility we have for the future, but also an intellectual challenge with unexperienced problems. With a clear vision and the ability of design, we must think outside the box and solve the global-scale problems.

Sustainable food supply for 9 billion people



PM=Project Manager


FUJIWARA Toru


TAKEYAMA Haruko


SHIMIZU Tatsuya


HINOMOTO Norihide


KOIKE Satoshi


YURA Kei


TAKAHASHI Shin-Ichiro


FURUKAWA Hidemitsu

R&D Projects

Food Production

Developing environmentally robust crops based on a new design approach

Project Manager: **FUJIWARA Toru**, Professor, The University of Tokyo

Outline: The breeding process will be substantially faster with digital designing technology to develop crops which can be grown in extreme environments.

Enhancing soil microbial functions based on detailed understandings of soil ecology

Project Manager: **TAKEYAMA Haruko**, Professor, Waseda University

Outline: The complex interaction of soil microbiology will be analyzed in detail and controlled to allow optimal crop and soil management.

Sustainable circular food production system driven by animal cells and algae

Project Manager: **SHIMIZU Tatsuya**, Professor, Tokyo Women's Medical University

Outline: Sustainable food will be produced through a circular animal cell culture system using algae as nutrients and recycling waste culture fluid.

Developing non-chemical pest controls

Project Manager: **HINOMOTO Norihide**, Professor, Kyoto University

Outline: Insect pests will be managed through a combination of non- chemical methods such as blue laser rays, new natural enemy strains and microbiological techniques.

Raising cows with less methane emission

Project Manager: **KOIKE Satoshi**, Professor, Hokkaido University

Outline: Methane emission will be substantially reduced by controlling microorganisms in cows' rumens.

Food Consumption

Producing food and feed from insects fed with food wastes

Project Manager: **YURA Kei**, Professor, Ochanomizu University

Outline: Food and feed will be produced from unused resources such as food waste, with the efficient metabolism of insects such as crickets and black soldier flies.

Developing food through an AI nutrition system

Project Manager: **TAKAHASHI Shin-Ichiro**, Professor, The University of Tokyo

Outline: Food and nutrition suggestion will be made with AI technology to meet personal needs and conditions.

Reducing Food Loss with “Unused Foodstuffs” × “Cold Energy of LNG”

Project Manager: **FURUKAWA Hidemitsu**, Professor, Yamagata University

Outline: We will manufacture hydrogel powder using unused foodstuffs and LNG cryogenic energy (cold energy generated when liquid natural gas vaporizes), establish long-term storage technology in ultra-low temperature warehouses to create added value for unused foodstuffs, and aim to build a social system that promotes ethical consumption.

Program Director

CHIBA Kazuhiro

https://www.naro.go.jp/laboratory/brain/english/moon_shot/

6

Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.

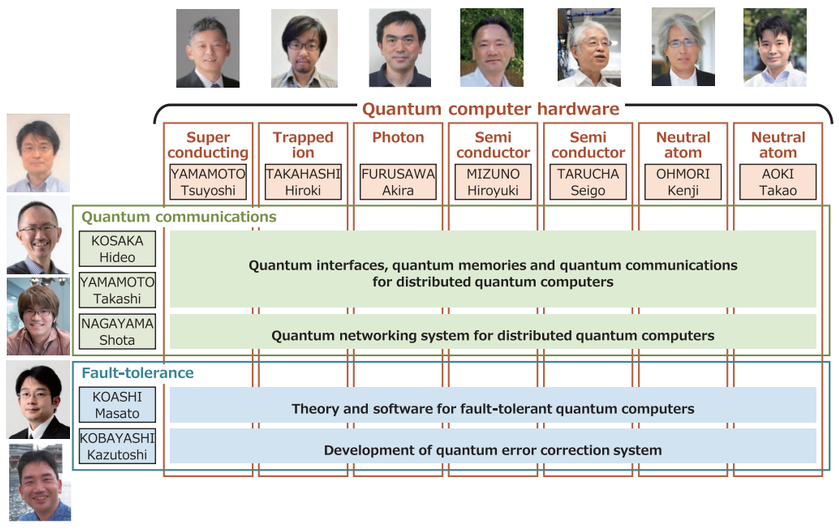
Program Director (PD) **KITAGAWA Masahiro** Director, Center for Quantum Information and Quantum Biology, Osaka University

Outline

While it is said that the progress of conventional computers is reaching its limits, it is important to be able to respond to the explosion of information processing demands. If we want quantum computing to rapidly solve our numerous and complex social problems, we need a fault-tolerant universal quantum computer that can perform precise computation while correcting quantum errors. In order to realize such a fault-tolerant universal quantum computer we are conducting R&D into the relevant hardware, software, networks, and related quantum technologies.

Message from PD

In order to realize a fault-tolerant universal quantum computer, it is necessary to integrate a huge number of qubits, provide redundancy using quantum error correcting codes, and reduce the physically arising quantum error to below the fault-tolerant threshold. Therefore, we aim to develop a certain scale of quantum computers and demonstrate the effectiveness of quantum error correction. Considering the possibility of massively integrated quantum computers through quantum communication, R&D projects will be implemented in three categories: '1) hardware', '2) communication networks', and '3) theory and software'. Specifically we would like R&D projects in each category to compete for feasibility, collaborate across categories, and conduct R&D to achieve the Moonshot Goal.



R&D Projects

Research and Development of Theory and Software for Fault-tolerant Quantum Computers

Project Manager: **KOASHI Masato**
Professor, Graduate School of Engineering, The University of Tokyo

Outline: This project aims to construct a co-design model encompassing qubit design, fault-tolerant architecture, and compilers and programming languages for efficient computation through collaborations of researchers in quantum information, architecture, and specific physical systems, thereby endeavoring to realize a large-scale quantum computer by the year 2050.

Development of Quantum Interfaces for Building Quantum Computer Networks

Project Manager: **KOSAKA Hideo**
Director of Quantum Information Research Center / Professor of Faculty of Engineering and Institute of Advanced Sciences, Yokohama National University

Outline: This project aims to develop a quantum interface in which quantum memory is combined with an optomechanical crystal, in order to connect the superconducting qubit and the communication photon, towards realization of a large-scale superconducting quantum computer by 2050.

Fault-tolerant Quantum Computing with Photonically Interconnected Ion Traps

Project Manager: **TAKAHASHI Hiroki**
Assistant Professor, Experimental Quantum Information Physics Unit, Okinawa Institute of Science and Technology Graduate University

Outline: This project aims to develop ion trap devices that facilitate building large-scale systems beyond the limitations posed by conventional approaches. The new approach is based on a novel idea of photonically interconnecting multiple ion traps. Thereby we aim to realize large-scale quantum computing by 2050.

Development of Large-scale Fault-tolerant Universal Optical Quantum Computers

Project Manager: **FURUSAWA Akira**
Professor, School of Engineering, The University of Tokyo/Deputy Director, Riken Center for Quantum Computing, Riken

Outline: This project aims at the realization of large-scale fault-tolerant universal quantum computers based on a "quantum look-up table" by 2050, which work at room temperature. Here, the "quantum look-up table" is originally developed by ourselves.

Large-scale Silicon Quantum Computer

Project Manager: **MIZUNO Hiroyuki**
Distinguished Researcher, Center for Exploratory Research, R&D Group, Hitachi, Ltd.

Outline: This project aims to achieve large-scale integration of silicon qubits by utilizing silicon semiconductor integrated circuit technology.By 2050, we aim to achieve a large-scale quantum computer featuring high integration and low power consumption.

Quantum Cyberspace with Networked Quantum Computers

Project Manager: **YAMAMOTO Takashi**
Professor, Graduate School of Engineering Science/Deputy Director, Center for Quantum Information and Quantum Biology, Osaka University

Outline: This project aims to develop elemental technologies for networking quantum computers with photons, atoms, semiconductors and so on, aiming to network small and medium quantum computers. We further promote networked quantum computers on a larger scale towards the achievement of universal quantum computation by 2050.

Development of Integration Technologies for Superconducting Quantum Circuits

Project Manager: **YAMAMOTO Tsuyoshi**
Research Fellow, Secure System Platform Research Laboratories, NEC corporation

Outline: This project aims to develop hardware technologies required for scaling up the circuit of superconducting qubits in order to accelerate R&D of superconducting quantum computers. Using these technologies we aim to realize large-scale superconducting quantum computers by 2050.

Large-scale quantum hardware based on nanofiber cavity QED

Project Manager: **AOKI Takao**
Professor, Faculty of Science and Engineering, Waseda University

Outline: This project aims to develop novel quantum-computing hardware based on nanofiber cavity QED. By 2050, we aim to develop large-scale distributed quantum-computing hardware and to realize a fault-tolerant universal quantum computer and a quantum internet

Large-scale and high-coherence fault-tolerant quantum computer with dynamical atom arrays

Project Manager: **OHMORI Kenji**
Professor /Chairman, Institute for Molecular Science, National Institutes of Natural Sciences

Outline: We will implement a "dynamical qubit array" in which a large number of cold-atom qubits are assembled with optical tweezers, and each of them is moved arbitrarily and at high speed to perform gate operations as well as error detections and corrections. Furthermore, under close industry-academia collaborations, all components will be integrated and packaged to achieve unprecedentedly high stability and usability. Through these innovations, we aim to realize a fault-tolerant quantum computer that will revolutionize economy, industry, and security by 2050.

Development of a Scalable, Highly Integrated Quantum Error Correction System

Project Manager: **KOBAYASHI Kazutoshi**
Professor, Department of Electrical and Electronic Engineering, Kyoto Institute of Technology

Outline: To realize an error-tolerant general-purpose quantum computer, this project addresses the technical issues of algorithms and scalable backends for classical hardware for error correction, scalable quantum-to-classical input/output frontends, semiconductor chips for backend/frontend, and cryogenic operation of optical integrated circuits for high bandwidth and low power quantum-classical input/output. Our challenge will be a technical breakthrough to implement a general-purpose fault-tolerant quantum computer by 2050.

Development of scalable Silicon quantum computer technology

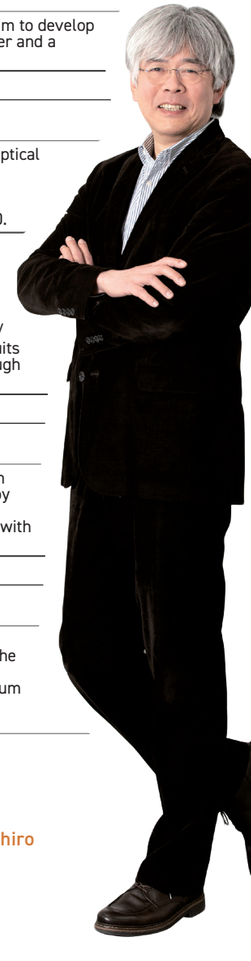
Project Manager: **TARUCHA Seigo**
Group Director, RIKEN Center for Emergent Matter Science /Team Leader, RIKEN Center for Quantum Computing

Outline: This project aims to develop scalable technologies for Silicon quantum computer. We will use sparse integration and medium-distance quantum coupling to implement a unit structure of qubits and scale up the qubit system by increasing the number of the unit structures. Based on this method we will develop fundamental technologies appropriate to implement large-scale quantum computers by 2030, and expand the technologies in cooperation with the semiconductor industry to implement universal quantum computers by 2050.

Scalable and Robust Integrated Quantum Communication System

Project Manager: **NAGAYAMA Shota**
Project Associate Professor, Graduate School of Media and Governance, Keio University

Outline: In this project, we will build a testbed for a general-purpose quantum communication network, which is a key technology for distributed large-scale quantum computers, and integrate hardware and software to demonstrate the principles and technologies of communication architectures and protocols with a view to actual operation.
The results of this project will lead not only to distributed large-scale quantum computers but also to the quantum Internet, and will contribute to the realization of a world in which quantum information can be freely generated, distributed, and processed.



Program Director
KITAGAWA Masahiro

https://www.jst.go.jp/moonshot/en/program/goal6/

7

Realization of sustainable care systems to overcome major diseases by 2040, for enjoying one's life with relief and release from health concerns until 100 years old

Program Director (PD) **HIRANO Toshio** Professor Emeritus, Osaka University, President, Osaka International Cancer Treatment Foundation

Outline

In recent years, diseases that are caused by a combination of environmental and genetic factors, such as so-called lifestyle-related diseases and diseases associated with aging, have come to have a significant impact on people in Japan, and this trend is expected to continue in the future. As the average life expectancy is increasing, the importance of prevention in addition to diagnosis and treatment will increase as we face the challenge of dealing with such diseases in order to further extend healthy life expectancy. The key is to live with as few limitations as possible even after suffering from a disease. For this reason, this R&D program will promote research and development in order to achieve the goal by 2040.

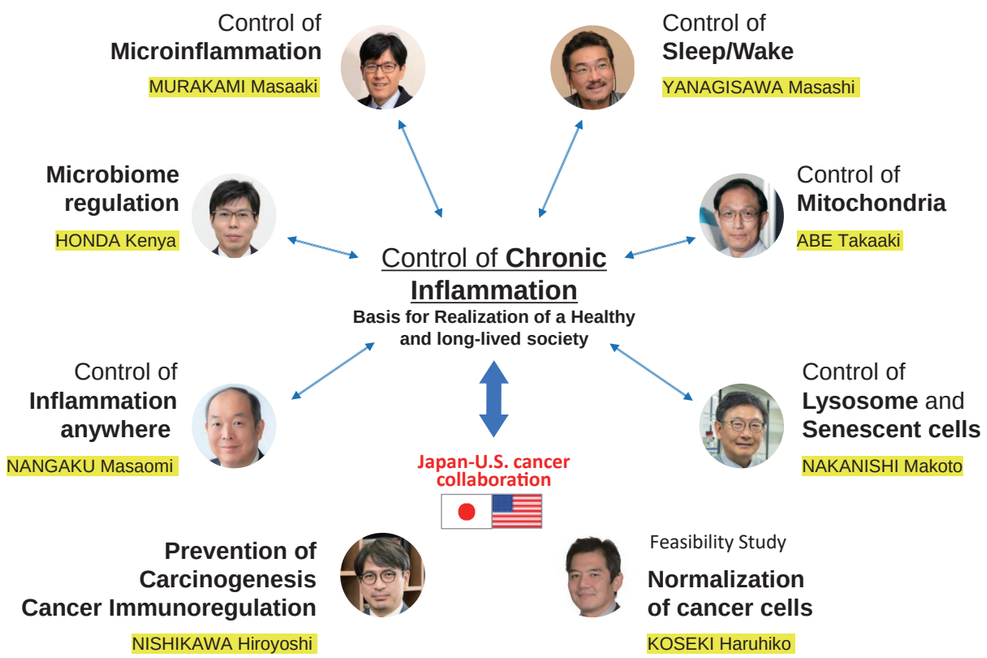
Message from PD

In order to realize a healthy society with a long life expectancy, it is important to provide medical care that maintains QoL (quality of life, that is, people feel comfortable), and does not just treat diseases in the past. Medical care includes treatment, prevention, rehabilitation, etc., and also a daily life after receiving medical care. We believe that QoL is an important perspective in the provision of medical care itself and in all the aspects of life after medical care. Cancer, brain disease, cardiovascular disease, etc., which are major diseases in a healthy and long-lived society, are considered to be lifestyle-related diseases rooted in genetic factors, lifestyle habits from infancy such as diet, exercise, and rest, and aging (life course). The most fundamental keyword for these diseases is chronic inflammation (It is a condition in which inflammatory reactions are mild but persist for a long time and become chronic. When such a inflammation persists, abnormalities in the function and structure of biological tissues occur, leading to various diseases.). We will continue our research and development projects based on this perspective of chronic inflammation.

Goal 7 Realization of sustainable care systems to overcome major diseases by 2040, for enjoying one's life with relief and release from health concerns until 100 years old.

3 Targets

- Realization of a society where everyone can prevent diseases spontaneously in daily life
- Realization of medical networks accessible for anyone from anywhere in the world
- Realization of drastic improvement of QoL without feeling load (realization of an inclusive society without health disparity)



R&D Projects

Mitochondrial Medicine

Project Manager: **ABE Takaaki**
Professor, Graduate School of Biomedical Engineering/Graduate School of Medicine, Tohoku University

Outline: To perform a comprehensive and integrated analysis of the "mitochondrial-gut flora association" to clarify which mitochondria and gut microbiota regulate the host, and develop non-invasive diagnostic methods and new therapeutic agents. We aim to achieve healthy longevity by detecting mitochondrial dysfunction at an early stage by intervening and treating it by 2040.

Extending healthy lifespan by eliminating senescent cells

Project Manager: **NAKANISHI Makoto**
Professor, The Institute of Medical Science, The University of Tokyo

Outline: This research project aims to develop innovative technologies that eliminate senescent cells (senolysis) which cause tissue microinflammation as a common pathogenesis of aging and age-associated disorders. Thereby, we will establish medical systems for the extension of healthy lifespan through which various age-associated tissue dysfunctions and disorders will be dramatically improved. In addition, we will also develop technologies that measure senility and establish medical networks that can be easily accessed by everyone and everywhere.

Regulating microinflammation: Preventing disease through quantum and neuromodulation technologies

Project Manager: **MURAKAMI Masaaki**
Professor, Institute for Genetic Medicine, Hokkaido University

Outline: Tissue-specific disease-related microinflammation develops around blood vessels during presymptomatic disease. Currently, there is no method to detect and eliminate this microinflammation. In this proposal, we aim to establish two novel technologies to reset the presymptomatic disease state to the healthy state: quantum measurements and AI-based information integration analysis. First, we will detect a weak but minimal level of IL-6 amplifier activation that leads to the development of tissue-specific microinflammation. Then, we will establish neuromodulation technologies to eliminate the microinflammation via specific neural circuits including gateway reflexes.

Deciphering and Engineering Sleep and Hibernation -- The Future of Medical Care

Project Manager: **YANAGISAWA Masashi**
Director/Professor, International Institute for Integrative Sleep Medicine, University of Tsukuba

Outline: Through elucidating the neurophysiological roles and regulatory mechanisms for two immobile modes of animal behavior, sleep and hibernation, we will develop technologies to control sleep and induce hibernation in humans, transforming the future medicine. Induced hibernation will be a step forward to space expedition, a dream of humankind.

Bring hospital into home toward controlling inflammation at home

Project Manager: **NANGAKU Masaomi**
Professor, Department of Nephrology and Endocrinology, The University of Tokyo Hospital

Outline: We will establish technologies analyzing gases emitted from human skin to monitor health condition and then research and develop technology that produces exercise-like effects (exercise substituting therapy and exercise mimicking drugs). By building a medical network that connects wearable sensors and hospitals to enable home diagnosis, we aim to realize a healthy longevity society.

Understanding and harnessing the role of the gut microbiome in healthy longevity

Project Manager: **HONDA Kenya**
Professor, School of Medicine, Keio University

Outline: We will illuminate the structure of metabolites produced by intestinal microbiota, which are currently poorly defined, and understand their operating principles as well as their effects on the nervous and immune systems. Through these studies, we aim to conquer Alzheimer's disease, Parkinson's disease, and chronic inflammation, realizing the unprecedented prevention and treatment methods.

A world of zero cancer risk created by rejuvenation using cell lineage conversion

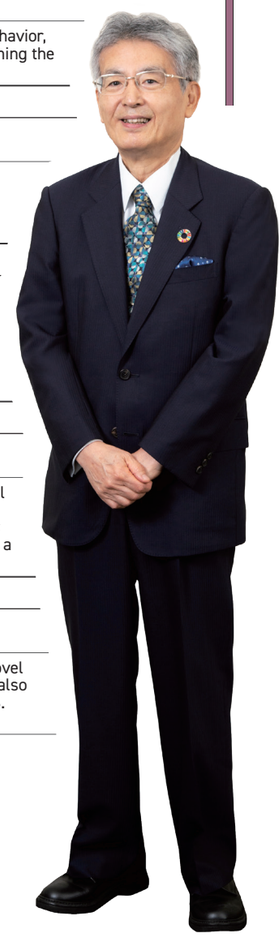
Project Manager: **KOSEKI Haruhiko**
Deputy Director, RIKEN Center for Integrative Medical Sciences

Outline: Chronic inflammation, which causes aging and cancer, can be a "double-edged sword" because it has the potential to cause "cell lineage conversion" such as cell rejuvenation.
By applying the mechanism of the reprograming in the cells of regenerative medicine, We will develop a technology to "reverse cancer tissues to normal tissues" via cell lineage conversion. Our interdisciplinary approach involves a multi-racial, large-scale clinical studies based on the Japan / US cooperation.

Actualization of a cancer-free society through regulation of chronic inflammation

Project Manager: **NISHIKAWA Hiroyoshi**
Professor, Graduate School of Medicine, Nagoya University

Outline: We will elucidate the mechanism of the inflammation-precancerous state-carcinogenesis transition and establish novel technologies to detect cancer-initiating cells at an ultra-early stage based on immune-genomic analysis. We will also work on preventive medicine and new drug discovery / development using wearable devices, etc. The Japan-U.S. team will strongly pursue this program to realize a "society with zero incidence of cancer".



Program Director
HIRANO Toshio

https://www.amed.go.jp/en/program/list/18/03/001.html

8

Realization of a society safe from the threat of extreme winds and rains by controlling and modifying the weather by 2050.

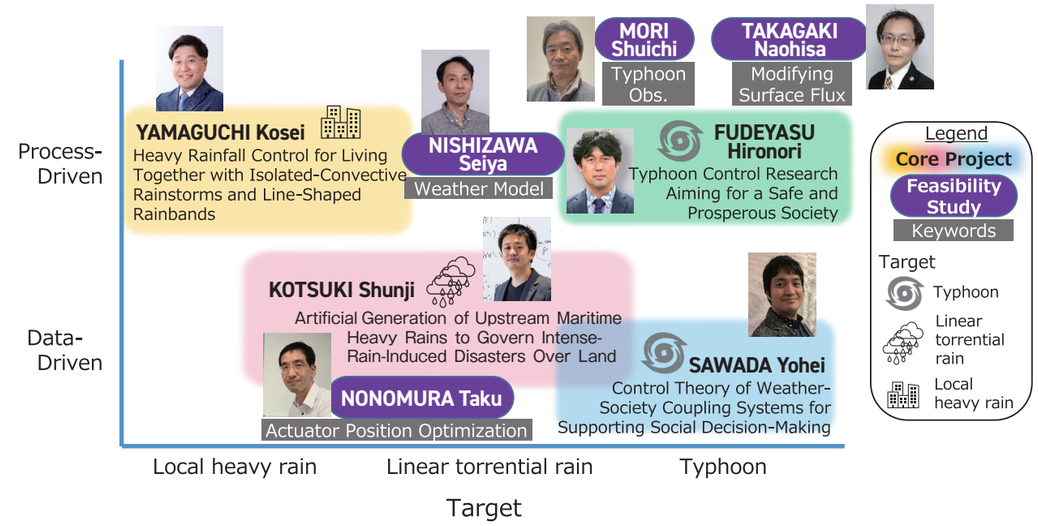
Program Director (PD) **MIYOSHI Takemasa** Team Leader, Center for Computational Science, Data Assimilation Research Team, RIKEN

Outline

Global warming means that wind and flood damage caused by extreme weather events such as typhoons and torrential rains are becoming more severe and frequent. If it is possible to change the intensity, timing, and/or location of extreme weather events that lead to disasters, it may be possible to avoid or dramatically reduce the resulting damage. In this program, we will conduct R&D aimed at: gaining a deeper understanding of extreme weather, which is essential for the development of weather control theory; improving weather forecasting technology such as weather modeling, data assimilation and ensemble methods; and realizing weather control technology that is socially, technically, and economically feasible.

Message from PD

Our goal is to significantly reduce the damage caused by extreme windstorms and floods, which are becoming more severe due to global warming and other factors, by developing weather control technology to change the intensity, timing, and location of typhoons and torrential rains. In our R&D we will combine control theory using numerical simulations, control technology that applies artificial disturbances to the atmosphere, and elements related to fundamental mathematics and ELSI. Weather control has long been a dream of humanity, and through my leadership as PD I hope to realize it as an open technology.



R&D Projects

Control Theory of Weather-Society Coupling Systems for Supporting Social Decision-Making

Project Manager: **SAWADA Yohei**
Associate Professor, Graduate School of Engineering, The University of Tokyo

Outline: This project aims to develop meteorological control theory that will enable small external forces to significantly change the weather. In addition, we also pursue the ability to precisely forecast a wide variety of impacts of meteorological disasters on society, which is necessary for social decision-making regarding weather control. By 2050, we aim to be able to control weather-society coupling systems based on democratic social decision-making processes in order to free the world from the fear of meteorological disasters.

Typhoon Control Research Aiming for a Safe and Prosperous Society

Project Manager: **FUDEYASU Hironori**
Director, Typhoon Science and Technology Research Center, Institute for Multidisciplinary Sciences, Yokohama National University/Professor, Faculty of Education, Yokohama National University

Outline: This project aims to develop principles and fundamental techniques to diminish typhoons, which are expected to become increasingly severe with climate change, to the level that disaster prevention infrastructure becomes effective. To this end, we will establish typhoon control theory through high-precision observations by aircraft, ships and satellites, and the development of numerical models that reproduce the inner workings of typhoons. Furthermore, we will conduct disaster forecasting and impact assessment, and tackle the issues of social acceptability and consensus-building for typhoon control. By 2050, we will realize a society of safety and that is free from the threat of typhoons.

Heavy Rainfall Control for Living Together with Isolated-Convective Rainstorms and Line-Shaped Rainbands

Project Manager: **YAMAGUCHI Kosei**
Associate Professor, Disaster Prevention Research Institute, Kyoto University

Outline: This project aims to control the intensity of "guerrilla heavy rainfall" and "line-shaped convective heavy rainfall". Based on numerical meteorological models, field observations, and laboratory experiments, we will develop multiple control devices. We will construct a control system that considers the impact assessment and social accountability of heavy rainfall control, by using those devices at multiple points in time and in multiple phases. By 2050, we will contribute to the formation of a future society in which heavy rainfall control technologies integrate with nature and human society.

Artificial Generation of Upstream Maritime Heavy Rains to Govern Intense-Rain-Induced Disasters Over Land

Project Manager: **KOTSUKI Shunji**
Professor, Institute for Advanced Academic Research / Center for Environmental Remote Sensing, Chiba University

Outline: This project aims to develop a weather control technology that mitigates heavy-rainfall-induced economic damages by artificially generating heavy rain over the upstream ocean. Given the limitations of directly altering the atmosphere, we explore a weather control method for intentional generation of heavy rains with optimization of manipulations. We will also promote social science research on legal issues and environmental risk assessments in order to accelerate the practical application of our results. By 2050, we aim to establish a weather control technology that society can accept.

Estimation and Control of Air-Sea Momentum and Heat Fluxes of Typhoons

Project Manager: **TAKAGAKI Naohisa**
Professor, Graduate School of Engineering, University of Hyogo

Outline: To realize weather control, highly accurate weather forecasting is essential. In particular, for controlling typhoons, there are two bottlenecks: (1) low accuracy of typhoon intensity predictions; (2) difficulty of distinguishing natural and control effects. This project aims to solve these bottlenecks by investigating the mechanism of momentum and heat transfer across the sea surface under typhoons, and formulating the momentum and heat fluxes using parameters associated with wave-breaking and wind waves through a large laboratory experiment for simulating typhoons.

Development of an Atmospheric Simulation Model for Estimating the Probability of Local Atmospheric Phenomena

Project Manager: **NISHIZAWA Seiya**
Senior Scientist, RIKEN Center for Computational Science

Outline: To realize weather control, we must solve a bottleneck to determining the optimal control method: that it is difficult to accurately estimate the probability associated with properties of local atmospheric phenomena, such as location, time, intensity. This project aims to develop an atmospheric simulation model suitable for this estimation which solves several problems inherent to current atmospheric simulation models, developing new computation schemes that are qualitatively different from conventional ones.

Actuator Position Optimization for Large-Degree-of-Freedom Fields

Project Manager: **NONOMURA Taku**
Professor, Graduate School of Engineering, Nagoya University

Outline: To realize weather control, we need to solve the bottleneck that the positions for actuators to maximize weather control effects are unknown. This project aims to organize, develop and evaluate actuator position optimization methods. We will show through weather simulation experiments that the obtained actuator positions can be used to improve control effects.

Development of Unmanned Marine Observation Vehicles Essential for Forecasting and Monitoring of Typhoon Artificial Control

Project Manager: **MORI Shuichi**
Principal Researcher, Center for Coupled Ocean-Atmosphere Research (CCOAR) of Research Institute for Global Change (RIGC), Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Outline: To realize weather control, nature needs to be continuously monitored. For typhoons it is important to continuously monitor the marine atmosphere and ocean surface layer near the typhoon center, which play important roles in the typhoon development process. However, it is difficult to conduct this monitoring via aircraft or satellites, which means it is a bottleneck for weather control. This project aims to develop unmanned maritime vehicles that can be virtually moored near the area of a typhoon center and continuously observe the atmosphere-ocean data along the movement path of the typhoon.

https://www.jst.go.jp/moonshot/en/program/goal8/

Program Director
MIYOSHI Takemasa

9

Realization of a mentally healthy and dynamic society by increasing peace of mind and vitality by 2050.

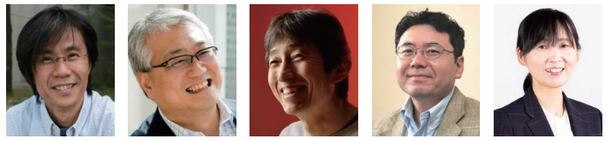
Program Director (PD) **KUMAGAI Seiji** Professor, Institute for the Future of Human Society, Kyoto University

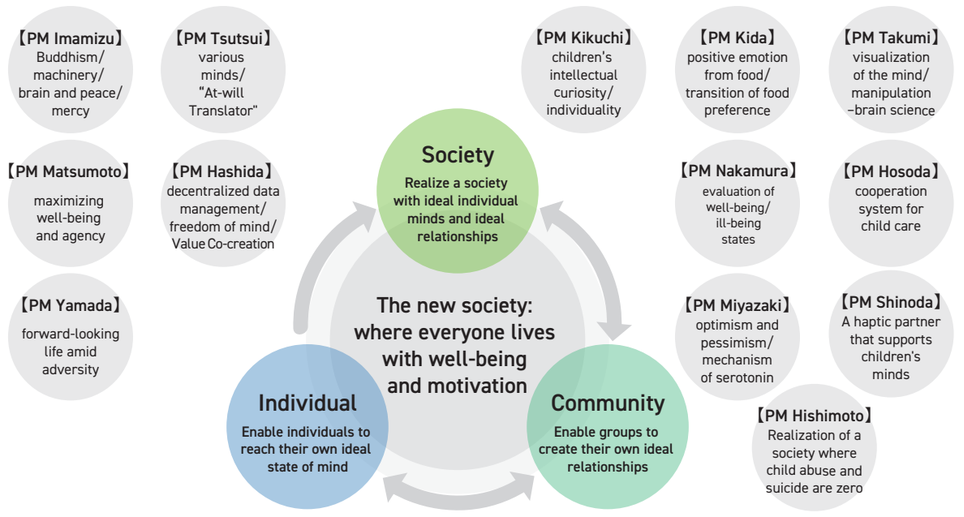
Outline

In recent years, social issues related to our mental states have become increasingly severe. The key to creating a mentally healthy and dynamic society is to develop a comprehensive understanding of mental states, and kind interpersonal and intergroup communication that will lead us in a more mutually beneficial direction.
Our R&D program aims to realize increased peace of mind and vitality by creating technology to realize “understanding of individual mental states and transitions” and "mental health support in terms of interpersonal and intergroup communication" so as to increase peace of mind and vitality.

Message from PD

We aim to realize a mentally healthy and dynamic society through development of technology that provides peace of mind and vitality. I believe it is necessary to discover the mechanisms behind our mental states, and use this practical knowledge for technology that will generate positive mental state transitions for users based on individual preferences. We will promote R&D using comprehensive knowledge gained by the fusion of different fields such as natural sciences, social sciences and humanities. Applying the expertise of enthusiastic researchers gathered from all over the world, together we will achieve our Moonshot Goal.


IMAMIZU Hiroshi | TSUTSUI Ken-Ichiro | HASIDA Koiti | MATSUMOTO Kenji | YAMADA Makiko



PM=Project Manager


KIKUCHI Mitsuru | KIDA Satoshi | TAKUMI Toru | NAKAMURA Toru | HOSODA Chihiro | MIYAZAKI Katsuhiko | SHINODA Hiroyuki | HISHIMOTO Akitoyo

R&D Projects

Asian humanities and brain informatics to enhance peace and compassion of the mind

Project Manager: **IMAMIZU Hiroshi**
Director, Cognitive Mechanisms Laboratories, ATR Brain Information Communication Research Laboratory Group

Outline: This project aims to investigate the dynamics of the human mind based on knowledge of Asian humanities, represented by Buddhism, and brain informatics and apply our investigations to society. We will construct models of mental-state personalities from large-scale surveys and detailed examinations of small groups, and develop technologies that accurately estimate and visualize brain dynamics. Our models and technologies will contribute to the development of meditation methods and their social applications that will enable people to understand themselves deeply, enhance the peace and vitality of their minds, and achieve a society which has compassion towards others as one of its most cherished values.

Development of "Jizai Hon-yaku-ki (At-will Translator)" connecting various minds based on brain and body functions

Project Manager: **TSUTSUI Ken-Ichiro**
Professor, Graduate School of Life Sciences, Tohoku University

Outline: This project aims to develop a "Jizai Hon-yaku-ki (At-will Translator)" supporting people's communications in various situations, which may be useful in realizing an inclusive society. Neuroscienctists, molecular biologists, and VR/AR and robotics engineers will collaborate to develop technologies to quantify states of mind, and methods for perceptual, cognitive and motor interventions. The Jizai Hon-yaku-ki will be produced by combining these technologies and methods, and facilitate the communication of individuals and small groups.

Freedom of Mind and Value Co-Creation through Decentralized Data Management

Project Manager: **HASIDA Koiti**
Group director, Center for Advanced Intelligence Program, RIKEN

Outline: This project aims to defend freedom of mind and promote value co-creation to strengthen both democracy and economic performance. Currently, centralized AI (CAI) and the attention economy threaten freedom of mind and democracy, and inhibit the creation of value from personal data (PD). This problem can be solved through decentralized management of PD, by which each individual's PD is fully utilized only by their personal AI (PAI). We will demonstrate that PAI creates much higher value than CAI, and will promote the replacement of CAI with PAI along with its democratic governance. We will also assist people to enhance the authenticity and diversity of information they utilize.

Maximizing well-being and agency on the basis of interpersonal comparison of brain indicators

Project Manager: **MATSUMOTO Kenji**
Professor, Brain Science Institute, Tamagawa University

Outline: This project aims not only to improve "happiness" at the level of individuals, but also to achieve aggregation and equality at the level of society. To this end, we will provide innovative technology to measure interpersonally comparable indicators of "happiness" from brain/neural activity. "Happiness" is enhanced not only by the experience of “well-being,” which benefits each person's life, but also by the recognition of “agency,” a way of life that each person has individually decided. We will study “well-being” and “agency” in future society using humanities and social science methods and virtual reality technology. Moreover, we will also achieve individual comparison of well-being and agency by elucidating brain indicators of subjective feelings “pleasure” and “aspiration”. In doing so we will bridge neuroscience studies and real-world activities, such as evaluating mobility policies in smart cities.

Realization of a society where people can live a Maemuki (forward-looking) life in the face of adversity.

Project Manager: **YAMADA Makiko**
Group Leader, Institute for Quantum Medical Science, National Institutes for Quantum Science and Technology

Outline: This project aims to realize a society in which people can live "forward-looking" lives even in the midst of adversity. To this end, we will clarify the diverse and multifaceted components of "positivity," calculate positivity indices by measuring physical posture and brain/ physiological reactions, and establish technologies to assist, train, and educate people on positivity factors tailored to their individual situations through positivity support technologies.

Protecting children's intellectual curiosity and individuality to realize a dynamic society

Project Manager: **KIKUCHI Mitsuru**
Professor, Graduate School of Medical Sciences, Kanazawa University

Outline: This project aims to realize an environment where everyone can grow up keeping their innate curiosity, thereby creating a society filled with active motivation and originality. Self-esteem damage in childhood can cause resilience to decline in later life, but by effectively preventing this type of problem we can realize a dynamic future society rich in intellectual curiosity. Specifically, we will use brain imaging technology to analyze children's brain characteristics, visualize the effects of interventions through optimized artistic activities, and implement them in society in collaboration with local governments.

Understanding the cognitively regulatory basis of food value that controls feeding behaviors

Project Manager: **KIDA Satoshi**
Professor, Graduate School of Agriculture and Life Sciences, The University of Tokyo

Outline: This project aims to elucidate the mechanisms by which favorite foods induce positive emotions such as pleasure and empathy with others, and the mechanisms by which food values are changed depending on experience. Though bad eating habits can themselves be the cause of disease, stress and ill-health can also result when trying to a convert to a healthier diet. Therefore we will develop technologies to improve food preference and make it enjoyable to eat healthy food, using a rodent model from a neuroscientific viewpoint, and try to achieve the goal of "increasing mental comfort and vitality" using food as a tool.

Development of a Neuroscientific Basis for Visualization and Manipulation of the Mind

Project Manager: **TAKUMI Toru**
Professor, School of Medicine, Kobe University

Outline: This project aims to visualize mice's brain functional network dynamics in action by developing a virtual reality (VR) system. We will quantify the "state of mind" of mice communicating with each other in a social environment as changes in the functional brain network. Furthermore, we will develop a technology for optical manipulation of the functional brain network using optogenetics to artificially induce changes in the "mental" state and clarify how the functional brain network responds to changes in the "mental" state and changes in behavior. Research on mice that allows direct manipulation of the brain will help develop a fundamental technology for elucidating the human mind.

Construction of an AIoT-based universal emotional state space and evaluation of well-/ill-being states

Project Manager: **NAKAMURA Toru**
Specially Appointed Professor, Institute for Datability Science, Osaka University

Outline: This project aims to construct an objective and universal emotional state space across species by integrating AI technology with Internet of Things (IoT)-based measurements of biological signals in daily life. Furthermore, the project will develop a method to evaluate well-being and ill-being states based on the dynamics of state transitions in the constructed emotional space.

Child Care Commons：Building the System Requirements of Alternative Relatives for Our Parenting

Project Manager: **HOSODA Chihiro**
Associate professor, Graduate school of information science, Tohoku university

Outline: This project aims to propose a Child Care Commons by clarifying the requirements for a system that allows diverse people to be involved in "child-rearing" flexibly and responsibly. We propose a system where everyone in society can voluntarily help raise children through the CCC.This system will increase people's peace of mind and vitality in three positions: parents (caregivers), children being cared for, and non-relatives participating in child-rearing. We aim to create a society where each person feels fulfilled, and a diverse range of people can play an active role.

Elucidation of the mechanism of serotonin over optimism and pessimism

Project Manager: **MIYAZAKI Katsuhiko**
Senior Staff Scientist, Neural Computation Unit, Okinawa Institute of Science and Technology Graduate University

Outline: This project aims to examine what kind of difference will occur in the serotonin neural network, which has been shown to play a role in regulating patience for future rewards, when mice perform the same behavior but the purpose of the behavior is different for "attainment of reward" or "avoidance of punishment". We hypothesize that serotonin works to regulate "optimism / pessimism" toward achieving the goal and we will examine the serotonin neural network by neural recording and neural manipulation of task performing mice. By clarifying the neural mechanism of “the optimism that creates patience” or “the pessimism that leads to giving up”, we aim to realize a society in which people can improve their " ability to overcome the difficulties of life" and "vitality of the mind".

A haptic partner that supports children's minds

Project Manager: **SHINODA Hiroyuki**
Professor, Graduate School of Frontier Sciences, The University of Tokyo

Outline: This project focuses on a haptic partner based on noncontact tactile reproduction technology that can replicate various tactile sensations in a wide skin area. The haptic partner is an AI partner that interacts with children through tactile senses in addition to visual and auditory senses. It influences emotions including pleasantness and arousal, stabilizing the children's minds and enabling them to achieve the desired mental response. The haptic partner's appearance and tactile feel change according to each child's preference and situation, becoming the optimum companion for each child.

Realization of a society where child abuse and suicide are zero

Project Manager: **HISHIMOTO Akitoyo**
Professor, Kobe University Graduate School of Medicine

Outline: By using our proprietary epigenome data resource for juvenile suicidal individuals and novel AMPA receptor recognition technology for human brain, we aim to 1) develop of biomarkers that accurately predict the presence or absence of child abuse and suicide risk, and 2) clarify abnormalities in epigenome status, gene expression, and AMPA receptors related to child abuse and suicidal tendency. Through these efforts, we aim to visualize child abuse and suicide risks, which are difficult for children to express themselves, elucidate the biological basis relevant to child abuse and related emotional instability even leading to suicide risk, and identify novel therapeutic targets, and finally realize a society where child abuse and suicide are zero.

Program Director
KUMAGAI Seiji

https://www.jst.go.jp/moonshot/en/program/goal9/

〈Three target areas〉

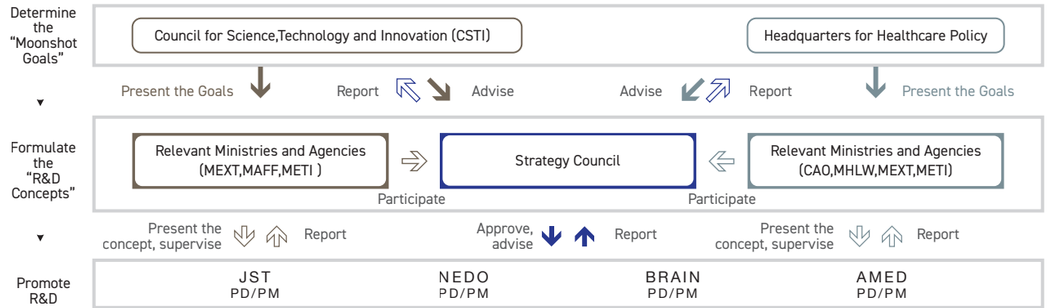
Society Overcoming the limits of our aging society by harnessing diversity and innovation.

Environment Supporting the recovery of the natural environment and sustainable urbanization.

Economy Exploring the frontiers of human activity with science and technology.

	Moonshot Goal	Society	Environment	Economy
1	Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050.	★		
2	Realization of ultra-early disease prediction and intervention by 2050.	★		★
3	Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.	★		★
4	Realization of sustainable resource circulation to recover the global environment by 2050.		★	
5	Creation of industry that enables sustainable global food supply by exploiting unused biological resources by 2050.		★	
6	Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.			★
7	Realization of sustainable care systems to overcome major diseases by 2040, for enjoying one's life with relief and release from health concerns until 100 years old.	★		
8	Realization of a society safe from the threat of extreme winds and rains by controlling and modifying the weather by 2050.		★	★
9	Realization of a mentally healthy and dynamic society by increasing peace of mind and vitality by 2050.	★		★
10	Realization of a dynamic society in harmony with the global environment and free from resource constraints, through diverse applications of fusion energy, by 2050.		★	★

〈Moonshot R&D Promotion System〉



〈History〉

2018.06 The 39th Council for Science, Technology and Innovation (CSTI)
- ▶ CSTI executive members highlighted necessity for Moonshot type R&D.

2019. 03 ~07 Goal-setting Visionary Council established.
- ▶ Council members discussed potential Moonshot Goals.
- ▶ Ideas welcomed from the general public regarding most important issues to be solved, and visions for an ideal future society.

2019.12 The Moonshot International Symposium
- ▶ Various stakeholders from around the world discussed future of the program and its goals.

2020.01 The 48th Council for Science, Technology and Innovation (CSTI)
- ▶ MS Goals 1 to 6 decided.

2020.07 The 30th Headquarters for Healthcare Policy
- ▶ MS Goal 7 decided.

2021.01 ~07 Researchers selected to create new MS Goals.
- ▶ Teams of ambitious young researchers brainstormed additional goals appropriate for the 'new normal' economy and society transformed by COVID-19.

2021.09 The 57th Council for Science, Technology and Innovation (CSTI)
- ▶ MS Goals 8 and 9 decided.

2023.12 The 70th Council for Science, Technology and Innovation (CSTI)
- ▶ MS Goal 10 decided.

〈About the Moonshot R&D Program〉

Cabinet Office

Moonshot Research and Development Program
https://www8.cao.go.jp/cstp/english/moonshot/top.html

〈Funding Agencies and their assigned Moonshot Goals〉

Japan Science and Technology Agency

Moonshot Goal : 1、2、3、6、8、9、10
https://www.jst.go.jp/moonshot/en/

NEDO New Energy and Industrial Technology Development Organization

Moonshot Goal : 4
https://www.nedo.go.jp/english/news/ZZCA_100007.html

BRAIN Bio-oriented Technology Research Advancement Institution

Moonshot Goal : 5
https://www.naro.go.jp/laboratory/brain/english/moon_shot/

AMED Japan Agency for Medical Research and Development

Moonshot Goal : 7
https://www.amed.go.jp/en/program/list/18/03/001.html

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