A photographer under the Fujiyama in the night. lisheng2121/AdobeStock

Made in Japan

Moonshot program for human well-being

Japan has a long tradition in cooperative programs. Usually these are down-to-earth, sintered through many rounds of expert discussions that have resulted in a consensus, which is formalised in an affidavit carrying the personal stamp signatures of the participants. Such group-centered endeavours for kaizen, continuous improvements made step by step, have often resulted in flawlessly perfect products.

In research and development (R&D), Japanese research associations follow similar mechanisms. With a theme often initiated and financially supported by the Ministry of Economy, Trade and Industries (Meti), usually through its project house New Energy and Industrial Technology Organisation (Nedo), public-private partnerships are formed whose members in industry, academia, and government jointly develop a new technology through open innovation, before they dissolve after several years (Table 1, p. 56).

Plans looking 30 years ahead

To address events that lie far ahead in the future, it takes a different concept to escape the endless compromises of consensus-based processes described before. The Japanese have found a group-oriented approach for such long-term programs as well. Japan has become known for developing plans looking 20 or 30 years ahead, such as "hydrogen-based society 2050"[4] based on expert estimates scrutinised by a Delphi procedure and followed by stage-gate processes during realisation. The latest master plan of this kind is the "moonshot programme for human well-being", the most ambitious element of Japan's current science, technology and innovation plan. It targets a visionary "society 5.0", a human-centered and inclusive society that reconciles economic growth and resolution of social issues. This plan "integrates cyberspace and physical space" and is based on data clouds, artificial intelligence, and quantum technology innovation hubs, together with "smart cities" that will serve as showcases for society 5.0.

The Moonshot Programme is defined as a portfolio of "inspiring and ambitious goals and concepts for challenging R&D on societal issues that are difficult to tackle but will have profound impact once resolved" (Table 2, p. 56). Programme managers are being asked to promote this port-

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Research Association	Target	Members	Initiated by
Biojet Fuel Consortium[1)]	Jetfuel from biomass (microalgae)	8 industry and public members	Nedo
Plastic Recycling Association[2)]	Solving problems of plastic waste	50 industry and public members	Nedo
Functional Food Study Group[3)]	Evidence-based information on functional food	32 industry and public members	Japan Bioindustry Association

Examples of current Japanese research associations.

Goal #1	A society in which human beings can be free from limitations of body, brain, space, and time
Goal #2	Ultra-early disease prediction and intervention
Goal #3	AI robots that autonomously learn, adapt to their environment, evolve in intelligence, and act alongside human beings
Goal #4	Sustainable resource circulation to restore the global environment
Goal #5	An industry that enables sustainable global food supply by exploiting unused biological resources
Goal #6	A fault-tolerant universal quantum computer that will revolutionise economy, industry, and security
Goal #7	Sustainable care systems to overcome major diseases, enabling individuals to enjoy life with relief and release from health concerns up to the age of 100

Targets of the "moonshot programme" (to be achieved by 2040 or 2050).

folio "without fear of failure". In 2020, around 830 million euros have been put aside for the moonshots.

The goals

Goal #1's central element is referred to as Cybernetic Avatars, including remote robots and 3D images as proxies but also empowering the physical and cognitive abilities of humans using information and communication technologies and robotics.

Goal #2 is built on a "whole body network atlas" that makes it possible to monitor functional changes in physiology throughout the course of an individual's life and identify transitions from a healthy state to a pre-symptomatic state, e.g., during the onset of cancer or dementia.

Goal #3 foresees artificial intelligence (AI) robots that have the same sensitivity as humans. As their physical abilities become equivalent to or better than those of humans, they be permitted to act alongside human beings by 2050.

Goal #6, a fault-tolerant quantum computer, is an obvious target for Japan's powerful computing industries.

Goal #7 is equally obvious in view of Japan's "super-ageing" society which, according to official projections, will have shrunk to about 100 million people (projections vary in view of immigration), one-third of whom are 65 years or older. The goal is to create a sustainable system to care for people up to the age of 100.

Goal X for the youth

In addition, there is a Goal X, defined as an "open call for ideas from youth-focused brainstorming teams, who will lead the next generation". It responds to the alarming fact that the number of young researchers in Japan who advance from master's to doctoral programmes has dropped to about 9 percent, about half the number of 20 years ago.

We will now take a closer look at goals 4 and 5.

Cool and clean earth

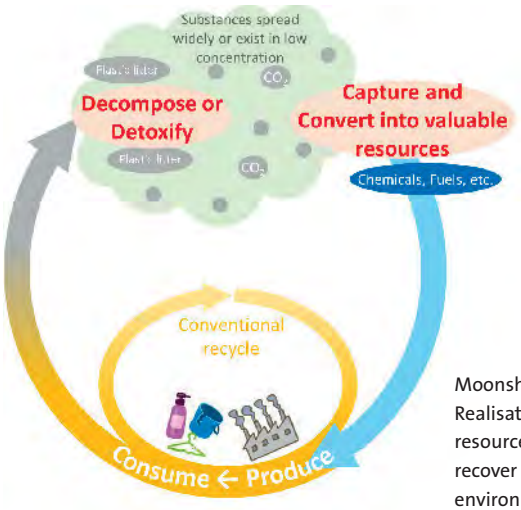
The programme director for goal #4, "cool earth & clean earth" (figure)[5)], is Kenji Yamji, Director-General of the Research Institute of Innovative Technology for the Earth (Rite) in Kyoto.[6)] The programme is composed of three project groups:[7)]

- Development of technologies to recover greenhouse gases(GHGs) and convert them into valuable materials.
- Development of technologies to recover nitrogen compounds and convert them into harmless or useful materials.
- Development of marine biodegradable plastics in which the timing and speed of degradability can be controlled.

Within this framework, a team led by Takafumi Noguchi, University of Tokyo, is studying calcium carbonate concrete (CCC),[8)] a recycled concrete material produced from atmospheric CO_2 and concrete wastes. If half of all concrete would be made with CCC in 2050, annual CO_2 emissions could be reduced by 20 million tonnes, and 6.2 million tonnes of CO_2 would be fixed.

For the mitigation of greenhouse gases generated from agriculture, the team led by Minamisawa Kimasu of Tohoku University is pursuing a programme called "Cool Earth via Microbes in Agriculture" and is already deliberating joint projects with European partners from the Soil Project, a Horizon Europe programme.[9)]

Nedo has organised several projects to address marine plastic litter. In addition to evaluation methods for marine biodegradability, new resins, new biomanufacturing processes, and new composite technologies will be developed, with the aim of achieving a new domestic market of 200,000 tonnes per year of marine biodegradable plastics by 2030.[10)]



Moonshot Goal #4. Realisation of sustainable resource circulation to recover the global environment by 2050.[5]

A considerably larger project, with 50 members and government support of 25 million euros for three years, is pursuing better recycling of waste plastic.[11] Key elements are

- sorting technology for optimal treatment,
- technology for recycling into materials that are comparable to the original plastic materials,
- technology for decomposition and conversion into petrochemical raw materials, and
- technology for highly efficient energy recovery by incinerating waste plastics that cannot be recycled.

Sustainable food supply

The programme director for Goal #5, "sustainable food supply without food-loss and environmental loading", is Kazuhiro Chiba, President of Tokyo University of Agriculture and Technology. The programme is made up of two subprojects:[12]

- food production systems that achieve expansion of food supply and conservation of the global environment, and
- food consumption system aiming at zero food loss and waste.

Food production will be based on novel production systems, such as the breeding of "super crops" that have incorporated drought-tolerant genes from their wild relatives. To this end, the present crop breeding concept needs to be changed "from selecting to creating", where key elements will be the use of divergent genetic resources, the use of big data and AI technologies, and the utilisation of genome editing and synthetic biology.

Another important effort concerns soil management. Haruko Takeyama of Waseda University will lead a project on "a resource-recycling food production system fully utilising biological functions of microorganisms and insects". The aim is to reduce the use of chemical fertilisers and pesticides through five research topics: a soil microflora atlas, improved crops, environmental control and measurement, cultivation management, and social science.

New protein sources such as insects will also be developed by a team led by Takashi Yura of Ochanomizu University. In fact, there already are pertinent start-ups such as Gryllus[13], which has developed technology to breed and harvest crickets (Gryllotalpidae); on this basis the food company Muji[14] has established their brand of "cricket crackers" – 100 grams of these crackers contain 60 grams of protein.

International cooperation

These examples demonstrate how Japan, challenged by ever stronger economic competition from its Asian neighbours, by a national debt burden of 260 percent of its Gross Domestic Product, and by the consequences of a super-ageing society, is following long-term visions in pursuing a 150-year strategy to create wealth through science and technology.

International cooperation is a clear priority, and there is considerable interest in interacting with European partners, e.g., through the European Horizon programme. Though Japan is not eligible for EU funding, it can participate in EU-funded projects if it covers its own costs. ■

1) *ihi.co.jp/en/all_news/2020/other/1196667_2042.html*
2) *pwmi.or.jp/pdf/panf1.pdf*
3) *jba.or.jp/activity/adv_biotech/study_group/functional-food/*
4) *a) R. Schmid,* Nachr. Chem. *2017,* 65, *1004; b) R. Schmid, H. Uchida,* Nachr. Chem. *2019,* 67(10), *24*
5) *www8.cao.go.jp/cstp/english/moonshot/concept4_en.pdf*
6) *jst.go.jp/moonshot/sympo/sympo2019/material/yamaji_20191217_ps2-discussion_191216–1223.pdf*
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