14th Annual Meeting

STS *forum* 2017

Summary

October 1, 2 and 3, 2017

Kyoto, Japan

Science and Technology in Society *forum*

Summary of STS *forum* 2017

STS *forum* 2017 - 14th Annual Meeting Program

September 30, October 1, 2 and 3, 2017

September 30, 2017 (Saturday)	
10:00-18:30	Registration [Grand Prince Hotel Kyoto] (for all STS *forum* participants)
18:00-20:00	Networking Plaza [Grand Prince Hotel Kyoto, Gold Room]

9:00-12:00	Regional Action on Climate Change Conference (RACC9) [Room 510]	
13:00-15:20	Future Leaders Network [Sakura]	
15:20-17:30	Dialogue between Future Leaders and Nobel Laureates [Sakura]	
15:00-17:30	6th Global Summit of Research Institute Leaders [Room C-2]	
14:00-16:40	Kyoto Symposium [Kyoto Chamber of Commerce and Industry]	

October 1, 2017 (Sunday)				
8:30	Doors open and registration starts at the Kyoto International Conference Center (ICC Kyoto)			
10:00-11:00	Opening Plenary Session 100: **Science and Technology for the Future of Humankind** [Main Hall]			
11:00-12:10	Plenary Session 101: **Sustainable Development** [Main Hall]			
12:10-13:40	Buffet Lunch [Sakura]			
13:40-15:20 Concurrent Sessions 102	Energy and Environment **Future Prospects of Oil and Gas** [Room K]	Life Sciences **Environment and Health** [Room B-1]	Engineering and Innovation **Industrial Innovation** [Room C-1]	Earth Science **Earth and Space** [Room J]
15:20-15:40	Coffee Break			
15:40-16:40	Plenary Session 103A: **Research and Innovation** [Main Hall]			
16:40-17:10	Coffee Break			
17:10-18:50 Concurrent Sessions 104	Energy and Environment **Nuclear Technology Prospects** [Room K]	Life Sciences **Genome Engineering** [Room B-1]	Engineering and Innovation **Future Nanomaterials** [Room C-1]	Earth Science **Water** [Room J]
18:50-21:00	105: Official Dinner [Event Hall]			

12:10-13:40	CEO Lunch Meeting [Room 103]				12:10-15:20
	Cooperation in S&T **Competition and Cooperation among Global Industries** [Room D]	S&T and Society **Innovation in Society** [Room C-2]	ICT **Artificial Intelligence (AI)** [Room B-2]	Cities and Mobility **New Transportation and Mobility Systems** [Room I]	S&T Ministers' Lunch & Roundtable [Annex Hall]
					15:30-17:00
	Plenary Session 103B: **The Role of Universities** [Room A]				CTO Meeting [Room E]
					16:50-18:50
	Cooperation in S&T **Science and Technology in Developing Countries** [Room D]	S&T and Society **Bridging Science and Technology with Society and Politics** [Room C-2]	ICT **Internet of Things (IoT)** [Room B-2]	Cities and Mobility **Smart Cities** [Room I]	University Presidents' Meeting [Swan]

October 2, 2017 (Monday)										
7:30	Doors open and registration starts at the Kyoto International Conference Center (ICC Kyoto)								8:00-8:45	
9:00-10:10	Plenary Session 200: **Science, Technology and Education in Digitalized Society** [Main Hall]								General Meeting	
10:10-10:40	Coffee Break								10:10-12:30	
10:40-12:20 Concurrent Sessions 201	Energy and Environment **Renewable Energy** [Room K]	Life Sciences **Advanced Medicine** [Room B-1]	Engineering and Innovation **New Manufacturing Technologies** [Room C-1]	Earth Science **Disaster Prevention and Resilient Society** [Room J]		Cooperation in S&T **Collaboration among Academia, Industries and Government** [Room D]	S&T and Society **Science, Technology and Engineering Education** [Room C-2]	ICT **Big Data** [Room B-2]		Funding Agency Presidents' Meeting [Room E]
12:20-13:30	Lunch [Sakura]									
13:30-14:30	Plenary Session 202A: **Population and Resources** [Main Hall]					Plenary Session 202B: **Science and Technology in Business and Finance** [Room A]				
14:30-14:50	Coffee Break									
14:50-16:30 Concurrent Sessions 203	Energy and Environment **Best Mix of Energy** [Room K]	Life Sciences **Healthy Aging** [Room B-1]	Engineering and Innovation **Robotics and Autonomous Systems** [Room C-1]	Earth Science **Climate Change and Ocean** [Room J]		Cooperation in S&T **Science and Technology Diplomacy and International Collaboration** [Room D]	S&T and Society **Policy Making in Science and Technology based Society** [Room C-2]	ICT **Cybersecurity** [Room B-2]	14:40-16:40 Academy of Science Presidents' Meeting [Room 104]	14:40-16:40 Academy of Engineering Presidents' Meeting [Room 103]
16:30-16:50	Coffee Break									
16:50-18:00	Plenary Session 204: **Delivering Health Care to the World** [Main Hall]									
18:00-18:30	Move to Kenninji Temple (Shuttle bus provided from ICC Kyoto)									
18:30-20:30	205: Special Buffet Dinner at Kenninji Temple									

October 3, 2017 (Tuesday)	
8:00	Doors open and registration starts at the Kyoto International Conference Center (ICC Kyoto)
9:00-11:00	Plenary Session 300: **Key Messages from Concurrent Sessions** [Main Hall]
11:00-11:40	Coffee Break
11:40-12:30	Closing Plenary Session 301: **Development and Sustainability for the Future of Humankind** [Main Hall]
12:30-13:30	302: Farewell Buffet Lunch [Swan]

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Plenary Sessions

Science and Technology for the Future of Humankind

[Chair]
Omi, Koji, Founder and Chairman, Science and Technology in Society *forum* (STS *forum*), former Minister of Finance, JAPAN

[Speakers]
Abe, Shinzo, Prime Minister, Government of Japan, JAPAN
Dvorkovich, Arkady, Deputy Prime Minister, Government of the Russian Federation, RUSSIA
Holliday, Jr., Charles O., Chairman, Royal Dutch Shell plc, NETHERLANDS
Sakakibara, Sadayuki, Chairman, Keidanren (Japan Business Federation); Senior Advisor, Toray, Industries, Inc., JAPAN

Opening Remarks

Mr. Koji Omi, Founder and Chairman, Science and Technology in Society *forum* (STS *forum*); former Minister of Finance, opened the 14th Annual Meeting and expressed his gratitude to the participants for their attendance and the sponsors for their support.

Chair: Omi, Koji

Amidst a changing global geopolitical environment, the exchanges promoted at STS *forum* are more crucial than ever before. Advances in science and technology have enriched and improved our lives, but at the same time create new problems that we must solve. These are the “lights” and “shadows” of science and technology. The fundamental concept of STS *forum* is to bring together leaders from government, industry, and academia, to discuss these “lights” and “shadows” for the betterment of society.

Science and technology is the key to promoting sustainability, for example in energy and environment. Nuclear energy remains an important energy option, under the conditions of safety security and non-proliferation.

Science and technology has also made great advances in areas such as ICT. ICT has improved productivity and convenience. At the same time, however, there has been a rise in related privacy and security issues. Additionally, biotechnology has seen progress as well, such as the further development of iPS technology.

STS *forum* also recognizes the need to nurture the next generation of science and technology leaders through its Future Leaders program. It is also committed to promoting the participation of women. In addition, the first CEOs meeting was held this year to stimulate more in-depth discussions among industry leaders.

Abe, Shinzo

Since last year’s annual meeting, three workshops have been held in Brussels, Delhi and Bali, to familiarize more people with the work of STS *forum*. In this way, STS *forum* continues to encourage global exchange and participation and it has developed from a mere conference into a global movement. This year’s meeting once again offers leaders an opportunity to deepen their human networks and enrich dialogue through frank and open discussions.

Mr. Shinzo Abe, Prime Minister of Japan, expressed his great belief in the power of science and technology to solve the structural issues faced by Japan. For example, in agriculture, the issue of the aging of farmers can be addressed through robotics, such as self-driving and automated tractors.
Japan is also promoting open innovation in self-driving cars. Leading Japanese and German car and component makers are engaging in a major self-driving experiment on Japanese public roads. Such international collaboration is essential for promoting innovation and it has been made possible by regulations that are kinder to innovators than those of any other country in the world. The guidelines in Japan allow companies that wish to test self-driving cars on public roads to do so anywhere, at any time, without a permit, provided there is someone in the car who is able to take over in case of an emergency.

Dvorkovich, Arkady

In addition, the Japanese government is also promoting such deregulation in other industries, including the pharmaceutical industry. It is possible to develop and put drugs to market in Japan as quickly as in any other country. There are even companies from California who have come to Japan to test new medicines.

In this age of science and technology, Japan is determined to turn itself into a cradle of innovation, allowing players from all over the world to work together to create something new.

Mr. Arkady Dvorkovich, Deputy Prime Minister of the Russian Federation explained that Japan was a key partner for Russia. The two countries have put together an eight-point economic cooperation plan. Trade relations also continue to thrive. At the same time Russia is also engaged in friendly cooperation with Japan, for example Japan became the partner country of INNOPROM-2017, Russia's largest international trade fair, held in Ekaterinburg.

This year marks the 60th anniversary of the first launch of an artificial satellite by the Soviet Union and Russia continues to highly value advances in science and technology. Russia launched a new digital economy initiative that will develop the infrastructure needed to promote the digital economy, while also eliminating obstructive regulations. Russia is also collaborating with Japan's 5th Science and Technology Basic Plan on cybersecurity, big data analysis, artificial intelligence, and the Internet-of-Things. It is also interested in advanced sciences, such as robotics, biotechnology, atomics, and quantum technologies. In addition, Russia is compiling a roadmap for the development of self-driving cars, which it will announce next year. Furthermore, Russia is promoting the development of blockchain technology.

In closing, Deputy Prime Minister Dvorkovich invited participants to attend the Open Innovations Forum in Moscow later this month, and the International Economic Forum in St. Petersburg in May 2018.

Holliday, Jr., Charles O.

Mr. Charles O. Holliday, Jr., Chairman, Royal Dutch Shell plc., believed that the world was facing ever-more difficult issues, but at the same time, there also existed many more potential solutions for tackling these problems. In light of this, he posed the question to the audience, "Why do we continue to disappoint ourselves with our progress?" One reason is that people are often looking at issues from two conflicting directions.

When people are looking in the same direction, however, remarkable progress can be made. For example, in Kenya, the introduction of a payment system tied to cell phones has made great strides in tackling poverty, and has been adopted in 10 other developing countries. Another example is Japan's Top Runner Program, which has been recognized as an effective method for promoting technological development and is now widely adopted around the world. Japan, and in particular Prime Minister Abe, is also leading the world in its vision for the development of a hydrogen society. These examples illustrate how two heads are better than one if they are pointed in the same direction.

Dr. Sadayuki Sakakibara, Chairman, Keidanren, began by reminding the audience of his remarks at STS *forum* two years ago, namely that behind every major turning point in human history was a major development in science and technology. This remains true today.

In particular, advances in the development of artificial intelligence technology offer huge potential. For example, it has already been incorporated as a key part of the manufacturing system in Germany and in China. Japan meanwhile, intends to integrate artificial intelligence even more deeply in society. This is its vision for Society 5.0, which aims to create a future society where the Sustainable Development Goals (SDGs) can be achieved. For example, Japan is faced with an aging and declining population, and thus an increasing labor shortage. Advances in robotics and artificial intelligence will increase productivity so as to overcome this shortage. This will achieve the SDGs of decent work and economic growth. Society 5.0 will also extend people's healthy life expectancies

Sakakibara, Sadayuki

by making use of medical information worldwide for individualized medicine and the development of new therapies. Thus, through Society 5.0, Japan will become a frontrunner in the achievement of the SDGs.

Keidanren has announced a plan for achieving for Society 5.0. The plan calls for joint public-private effort, through collaboration among government, industry, and academia. It is now time to start producing results and Japan expects to be able to demonstrate the fruits of Society 5.0 at the 2020 Tokyo Olympic and Paralympic Games. Osaka is also bidding to host the 2025 World Exposition, which would provide another opportunity for Japan to showcase Society 5.0 to the world. Finally, Japan is aiming to fully realize Society 5.0 by 2030, which is the target year for the achievement of the SDGs.

Sustainable Development

[Chair]

Murray, Cherry A., Benjamin Peirce Professor of Technology and Public Policy, John A. Paulson School of Engineering and Applied Sciences; Professor of Physics, Harvard University; former Director, Office of Science, Department of Energy, U.S.A.

[Speakers]

Seko, Hiroshige, Minister, Ministry of Economy, Trade and Industry (METI), JAPAN
Guo, Ping, Deputy Chairman of the Board, Huawei Technologies Co., Ltd., CHINA
Uchiyamada, Takeshi, Chairman of the Board, Toyota Motor Corporation, JAPAN
Williams, Keith E., President and Chief Executive Officer, UL LLC, U.S.A.

Opening Remarks

Dr. Cherry A. Murray welcomed the participants and shared the definition of sustainable development by the Brundtland Commission in 1987 in its World Commission on Environmental and Development report, as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." The report highlighted the need to promote economic and social advancement for all, in ways that avoid degradation. The Sustainable Development Goals (SDGs) continue this tradition. The SDG seek to achieve environmental preservation, social equality, and economic development.

Chair: Murray, Cherry A.

The world is undergoing a global economic transformation. Efforts by companies to protect the environment and achieve social inequality are in line with their efforts to promote prosperity and better quality of life.

Dr. Murray then quoted the September 2015 resolution of the United Nations General Assembly on the SDGs, highlighting the paragraph "We resolve, between now and 2030, to end poverty and hunger everywhere; to combat inequalities within and among countries; to

build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of women and girls; and to ensure the lasting protection of the planet and its natural resources. We resolve also to create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, taking into account different levels of national development and capacities."

While tremendous progress has been made in some areas, there has been unsatisfactory progress in others. Poverty has decreased from 36% of the global population in 1990 to 9% in 2016. However, there are still over 700 million people living in poverty today. Stunted growth resulting from malnourishment has decreased to 26% of the global population since 1990. Maternal mortality rates have fallen by 35% since 1990. Child mortality has also declined by 55% since 1990. 9% of school aged children are out of school, which, unfortunately, is the same percentage as in 2008. With regard to achieving gender equality and the empowerment of women and girls, women's participation in national parliaments reached 23% in 2017. In 2015, less than a third of middle and senior management positions were held by women. The percentage of people who only have access to unsafe water or unsafe sanitation has fallen by 45% since 1990, but a third of the world still uses unsafe water. More than 3 billion people continue to suffer from indoor pollution due to unclean cooking fuels. The use of renewable energies has increased only marginally. As for climate change, although the Paris Agreement entered into force, and over 180 countries have ratified the

agreement, the United States, the second largest greenhouse gas emitter in the world, has announced that it will leave the agreement by 2020.

In order to continue to make progress, governments, businesses, and citizens must take leadership on science and technology issues.

Mr. Hiroshige Seko spoke about the Japanese government's vision to create a new world, promote innovation, and make the global environment more sustainable and robust. This vision is possible because of the vast technologies, knowledge and data that have been accumulated on factory floors in Japan.

However, these have not been effectively leveraged due to company and industrial silos. To overcome this, Japan is promoting the Connected Industries (CI) initiative. This initiative will utilize artificial intelligence, sensing, robotics, and other technologies to connect the knowledge, technology, and data across different companies and industries.

The Japanese government will also modify regulatory frameworks to develop an environment that fosters collaboration among Japanese companies and also among Japanese and overseas companies. Japanese companies have record profits and the Japanese government will help companies direct these profits to investments for the future.

Mr. Ping Guo discussed the role of technology in sustainable development. ICT is the key enabler for the achievement of the SDGs, especially in areas such as health care, sustainable cities, industry innovation. Many traditional companies are using digital technologies to achieve sustainable solutions.

Leading elevator companies are working with Huawei on innovative solutions to link up elevators with applications and use intelligent systems to improve efficiency and design. For example, ICT can enable preventive maintenance, which reduces maintenance and operation costs.

In addition, big data can improve elevator design and make them more competitive. In the past, the data generated by elevator sensors was not effectively utilized. Huawei is changing this, allowing the optimized design of elevators.

To make such connected elevators work, wide-ranging collaboration is necessary. Huawei enables this with its software. Collaboration among all players across the entire eco-system is essential and Huawei intends to work closely together with all stakeholders.

Mr. Takeshi Uchiyamada shared the activities of Toyota Motor Corporation towards creating a hydrogen society, as an example of its efforts to promote sustainable development. The company firmly believes that a hydrogen society will make the world better place.

There are several reasons for this. First, hydrogen produces no CO_2 when reacting with oxygen. Second, it can be produced from a variety of primary energy sources and thus is secure from an energy perspective. It can also be produced from sewage and other renewable energy sources, thus reducing CO_2 emissions even further. Third, it is produced and consumed locally. Fourth, building links between hydrogen sources to the power grid will help create a truly sustainable society.

The Abe Administration has been promoting the development of a hydrogen society. A government council has produced a roadmap for this in 2014 and revised it in March this year.

Toyota will soon release MIRAI, a car that runs on hydrogen. It has also produced a fuel cell bus and a fuel cell forklift. Moreover, a number of companies, including Toyota, have signed a memorandum of understanding for the large-scale construction of hydrogen stations.

Efforts are not limited to Japan. A Hydrogen Council has been established as part of the World Economic Forum in Davos. Toyota is a member of the council and will do everything it can towards the realization of a hydrogen society. Toyota is also working to expand its activities to other countries, using MIRAI. Toyota is determined to stand on the frontlines and lead the way to the creation of a hydrogen society.

Mr. Keith E. Williams explained that UL stood at the interface between society, and science and technology, and shared examples of UL's contribution to sustainable development. In the area of chemical safety, UL is working on improving indoor air quality and identifying potentially harmful emissions from products in the home. UL is collaborating with a number of partners to identify exacerbators of childhood asthma, build air cleaning technologies, and develop fire-safe and chemical-safe furniture that is still affordable and usable.

In addition, UL is engaged in activities to achieve smart cities and smart societies. One of the key challenges is developing ways to connecting all the many different technologies that smart buildings and devices use and allow them to communicate with each other. Another is to further develop sensing technologies.

Another issue that UL is tackling is achieving zero waste to landfill. UL has developed certification for companies that send zero waste to landfills. In addition, an issue that will arise from the spread of electric vehicles is how to reuse and recycle all the batteries that such vehicles use.

Finally, UL has also developed a data aggregation platform that enables the effective use of data related to achieving sustainable development.

Discussion

Dr. Murray opened the discussion by asking the Mr. Seko about the Japanese government's activities for promoting innovation for sustainable development.

Mr. Seko said that Japan faced many challenges, including an aging society and declining population. Japan will lead the world in developing solutions for these issues through the CI program, thereby turning Japan's weaknesses into strengths.

Dr. Murray then asked Mr. Guo how Huawei was working with other companies to integrate its technologies.

Mr. Guo explained that as an ICT company, Huawei was a key partner for traditional companies that are seeking to digitalize. In addition, another challenge is making advanced technologies accessible to all parts of society. To that end, while smartphones are not affordable for a large part of the Kenyan population, Huawei has helped develop a mobile payment system that has improved lives and reduced poverty.

Next, Dr. Murray inquired about Toyota's efforts to create a hydrogen society.

Mr. Uchiyamada explained that a key challenge was developing the underlying infrastructure. Having the necessary government policy is important in this regard. Collaboration with energy companies is also essential.

Dr. Murray then asked Mr. Williams elaborate on how UL promoted collaboration.

Mr. Williams answered that collaboration had always been a core part of UL and that the company had established councils with external partners to that end. UL also collaborates with universities on projects of interest and provides funding for certain types of research.

To close the meeting, Dr. Murray highlighted the concept of connected industries but also collaborative competition, and the need to promote these ideas in a sustainable way.

Research and Innovation

[Chair]
Kleiner, Matthias, President, Leibniz Association, GERMANY

[Speakers]
Vidal, Frédérique, Minister, Ministry of Higher Education, Research and Innovation, FRANCE
Chubachi, Ryoji, President, National Institute of Advanced Industrial Science and Technology (AIST), JAPAN
Yukawa, Hidehiko, Managing Executive Officer, International Business and Cooperation Division, The Kansai Electric Power Company, Inc., JAPAN
Colwell, Rita R., Distinguished University Professor, Center for Bioinformatics and Computational Biology, University of Maryland; Professor, Bloomberg School of Public Health, and Johns Hopkins University, U.S.A.

Opening Remarks

Dr. Matthias Kleiner began by stating that science and technology constitute the most important part of the solution of various pressing issues like climate change, but that at the same time continuous dialogue and cooperation with society will be integral requirements. He referred to the idea of "Citizen Science," noting that the possibility has expanded considerably in recent years through new digital technologies, including the collection of data through smartphones.

Chair: Kleiner, Matthias

Dr. Kleiner then outlined the five topics for the session: (1) benefits arising from "Open Science" and interactions between knowledge-based science and application-based engineering; (2) impact of game changing technologies; (3) message for policymakers on how to best develop and use science and engineering; (4) the most important technology change in a lifetime; and (5) challenges and chances for Citizen Science.

Dr. Frederique Vidal stated that Open Science promotes opportunities to give access to information, methods, research data and new collaborations among researchers of different institutions and across countries. For rare diseases, for which there are few cases at the regional level, Open Science offers access to cases at the international level, which in turn will significantly change the conditions in which science is produced. Furthermore, Open Science is a positive move towards transparency and public availability of research results. Open innovation is instrumental in transforming industry towards Industry 4.0. Dr. Vidal underscored the importance of promoting open innovation, especially by forcing the mobility of researchers between public and private sectors. She emphasized that it is important to support the SDGs and insist on the Paris Agreement. Dr. Vidal said the main issue is to further develop Citizen Science and involve scientists in it to ensure that the results benefit both sides while closing the gap between them.

Dr. Ryoji Chubachi discussed the role of science and technology in the future. Before the Industrial Revolution, most production was dependent on manpower. After the invention of the steam engine, the manufacturing process changed from humans to machines. As a result, food was secured, and population increased rapidly. The Industrial Revolution was based on a model of innovative technology, resources, and capital. However, it had negative aspects, such as environmental destruction. In Japan as well, the Industrial Revolution achieved high economic growth from the 1950s to the 1970s but brought about water and air pollution.

AIST aims to realize a sustainable society and focuses on local solutions, which has included the establishment of the Fukushima Renewable Energy Institute. It plans to demonstrate hydrogen transportation during the 2020 Olympic Games. He concluded that, while the development of technology has destroyed human society, technology can also help realize a sustainable society.

Mr. Hidehiko Yukawa presented on three topics: 1) outlook of Japan's power business; 2) innovation in Japan; and 3) innovation in developing countries. Energy security is a priority issue in Japan because of its poor domestic resources and its nature as an isolated island. Electric companies have tried to diversify energy sources through nuclear and renewable energies. Nuclear power plays an essential role and its use should be resumed after its safety has been confirmed.

He said smart and state-of-the-art technologies are adopted at both the supply and demand sides. On the supply side, this includes clean coal technology, integrated coal gasification combined cycle, and carbon capture. In the renewable energy field, sophisticated power systems have been adopted such as combined batteries and satellite-based solar output prediction systems. On the demand side, information is provided to customers to help them save energy based on data from smart meters.

With regard to innovation in developing countries, Mr. Yukawa said it was their mission to share their experience and provide their technologies to developing countries. In developing countries, not only utilization of the latest technologies but also creation of sustainable models using existing technologies is essential. For example, the Kansai Electric Power Company (KEPCO) introduced the Dhiffushi Solar Ice Project in the Maldives. One issue is how to control fluctuations in PV output and the project uses an ice machine as a controllable load. In the Maldives, about 1,300 people make a living by fishing, and the ice made from the project is used to preserve the fish. Repeated dialogues with the islanders shed light on their need for ice. They no longer have to have ice shipped from other islands. He noted that such projects will provide an example to other countries.

Dr. Rita Colwell stated that the timeline between discovery and application, which was traditionally considered 20 to 50 years, has been shortening rapidly. A century ago the telephone was discovered and the landline was used for 70 years, which is now being replaced by cell phones and the i-phone. Today, ideas quickly become inventions and revolutionize society. With the development of next-generation sequencing, micro-bio has, in a short time, become a discovery and an application. Biological phenomena can not only be used for health applications, but also for generating energy. Bioreactors can be provided to waste reactors. There are huge societal rewards and benefits. At the same time, there is the challenge of gene editing. In medicine, it enables the determination of the genomes of individuals and their susceptibility to disease, while on the other hand, it offers the capability to make improvements in intelligence and health, an issue that must be considered immediately. In agriculture, gene editing is a mechanism by which gene coding can be introduced for vitamins so that nutrition is improved. In the area of climate, regulating bacteria in clouds can enhance precipitation. The speed at which discovery is being made and applied is rapid. Using creative and open science can provide results that can be immediately applied. The challenges are to understand and utilize microbial capabilities for humanity, and addressing the challenges is equally important.

Discussion

Dr. Kleiner asked whether the work of research and innovation is inclusive enough.

Dr. Vidal said it is not. She stated that a narrative needs to be created so that citizens understand how science and innovation contribute to their lives. There is a lack of links between society and scientists. Through Citizen Science and dissemination, they can help to be more inclusive and have more impact on society. They must also be inclusive for countries that still do not have sufficient technological devices to help them go from Society 2.0 or 3.0 directly to Society 4.0 or 5.0.

Dr. Kleiner asked if new innovative business models are inclusive enough.

Mr. Yukawa stated that they need to approach both the supply and demand sides. KEPCO adopts the smart meter, allowing them to understand the lifestyle of the people. This data can be reflected on the supply side approach, including innovation of new technologies such as the battery. He said it is uncertain whether the models are enough, adding that they need to maximize people's benefit from the models.

Dr. Kleiner asked when we will leave the age of the steam engine.

Dr. Chubachi noted that the Industrial Revolution business model consists of resources, innovative technologies, and capital but that this business model can no longer be maintained. He was unsure how long the steam engine will be kept.

Dr. Kleiner asked whether Citizen Science will change the mindset of not only the people but also of scientists.

Dr. Colwell responded that individuals, not scientists, are now gathering data out of interest, and that if citizens can participate with scientists, attitudes can be changed and this will be important.

Dr. Kleiner gave an example from Germany on how employees of a waste recycling company working in the early morning hours observe which animals are found in the streets of Berlin.

Q&A Session

A participant asked whether the rapid transition from discovery to innovation affects how science is carried out today and helps resolve outstanding problems.

Dr. Colwell said when an explosion occurred in the Gulf of Mexico, she was asked to establish an independent research program for which 500 million dollars would be available for ten years. Eight years into the research, it has allowed them to predict what would happen if a spill occurs in the Gulf of Mexico and learn about the ecological effects. This is because it was an industry-independent program focused on solving a problem but using basic research and predictability. She said how information is gathered to deal with problems in the future lends itself to studies that focus not only on physics, chemistry, and ecology, but are interdisciplinary.

A participant asked about the implications of the increased pace of research and innovation on how society adapts to changes in technology.

Dr. Chubachi responded that maintaining a good relationship with stakeholders in society is important, and that AIST partners with not only major companies but also with other stakeholders including local governments and NGOs to provide better solutions for the needs of society.

The Role of Universities

[Chair]
Maex, Karen, Rector Magnificus, University of Amsterdam, NETHERLANDS

[Speakers]
Hayashi, Yoshimasa, Minister, Ministry of Education, Culture, Sports, Science and Technology (MEXT), JAPAN
Guzzella, Lino, President, ETH Zurich – Swiss Federal Institute of Technology Zurich, SWITZERLAND
Yamagiwa, Juichi, President, Kyoto University, JAPAN
Lim, Chuan Poh, Chairman, Agency for Science, Technology and Research (A*STAR), SINGAPORE

Opening Remarks

Dr. Karen Maex began by emphasizing that universities are where academic freedom is fostered and global scientists can meet and collaborate. All countries must accept the freedom of movement of scientists and grant autonomy to universities. Universities have the three main tasks of education, research, and innovation. Research has helped bring innovation to society, and its challenges should be examined in societies that are changing dramatically.

Chair: Maex, Karen

Dr. Maex went on to say that we must overcome the barriers separating the humanities and the sciences, and examine how to reach out to society in an age of fake news. Interdisciplinary learning is vital and also popular with students. Students need to be taught new skills, with internationalization and a global skillset at the core. It is important to learn about other cultures, and emotional borders are, in that sense, often even more important than geographical borders. She noted that research leads to innovation, and innovation should bring about

better research. Innovation should be responsible, and we must emphasize maintaining our humanity amidst change.

Mr. Yoshimasa Hayashi touched upon Japan's postwar history of absorbing systems from the west, as well as its economic growth and struggles. Japan is now facing a turning point as it becomes a super-smart society with advanced technology and citizens who are increasingly living to over 100 years of age. The Japanese Government has established the Council for Designing 100-Year Life Society to examine the effects and policies necessary for such a society.

Universities play a vital role in addressing societal change. The youth population is rapidly dropping in Japan, and acquisition and application of new knowledge and skills, as well as richly diverse collaboration, must be developed. Pillars in addressing this are improvement of education and research, systemic reforms of education and research, and rectifying inequality in access to education. Initiatives include universities that foster necessary skills and also encouraging lifelong learning in the population. To activate innovation and stimulate a positive economic cycle, the Japanese government is aiming for a benchmark of 1% of GDP for R&D in universities and the public and private sector. In addition, young researchers, female researchers, as well as researchers from around the world are being supported.

Dr. Lino Guzzella spoke about Switzerland's education system, where a smaller portion of students move to university while others focus on vocational education. He emphasized that ethical, moral, and cultural questions should be examined in education, with extensive

interaction between all disciplines. As an example of critical thinking at ETH Zurich, he mentioned a seminar where physicists and philosophers debate together with students the role of the experiment as a scientific method. Learning how to ask the right questions is more important than simple rote learning.

Dr. Guzzella also mentioned that in the past education used to be confined to the wealthy and connected, but with the rise of the modern state education and research became a task of the society as a whole. Although some would prefer for scientists to be able to do their research entirely on their own, leaders in the field should aim for a broad access to education and knowledge that will benefit all of society.

Dr. Juichi Yamagiwa spoke about university reform to adapt to new societal trends, with strategies that include increasingly internationalized faculties, industry collaboration, and enhancement of universities' financial base. Universities must advance innovation for society as well as their own development as centers of knowledge. For example, Kyoto University utilizes its international hubs to foster students and researchers at all stages of their careers. International collaboration has an important role to play in addressing the growing wealth gap that is causing inequality of access to education. Together with global cooperation, the utilization of information and communication technology is vital. Tuition fees and semester systems must be adjusted to stimulate international student mobility.

Kyoto University is also establishing on-site laboratories on the campuses of partner universities around the world, and expects the on-site lab system will provide new avenues for hosting local students and implementing research collaboration with local companies. Kyoto University aims to develop new interdisciplinary areas to address global issues, especially the medical area. Implementing collaborative R&D with pharmaceutical companies has facilitated the launch of new medications, while R&D with companies such as Toyota has yielded major advances in the development of long-lasting batteries. Universities' funding difficulties have led to the need to find new monetary sources, such as the establishment of profit-making businesses and other fundraising initiatives. The Kyoto University Model of industry-academia collaboration entails investigating and understanding corporate and market needs, and then developing research projects to optimally meet those needs. It is vital, however, that together with increased university collaboration with industry and government, universities also maintain their autonomy and academic freedom.

Mr. Chuan Poh Lim stated that the Singapore government has consistently invested in education as an imperative, as people are the only resource. Mr. Lim shared that universities have played an important role in Singapore's development, and have been imparting the necessary knowledge, skills, values, and ethos to prepare generations of students for productive roles in the economy, and become engaged and responsible members of society.

In the digital age, Mr. Lim emphasized that the focus of teaching has to move beyond largely knowledge acquisition to become a platform for engagements in order to apply and deepen what students have learnt by themselves. In February this year, the Singapore government released a report on the Future Economy, of which the strategies articulated a shift in focus towards the development of skills mastery, creativity and innovativeness, and a mindset of lifelong learning. Of note, Mr. Lim cited an example whereby the universities were offering programmes to strengthen the nexus between skills acquisition and application through overseas internships and entrepreneurship opportunities. Mr. Lim also cited another example whereby the universities are also adopting a new pedagogy -- known as a flipped classroom model. This model allows students to access online course content on their own time before class, while class time is devoted to problem-based discussions that stimulate critical thinking and active engagements. Through the process of continual reform and improvement, Mr. Lim hopes that the universities will remain relevant and effective in preparing the next generation for a more competitive and rapidly changing digital world.

Q&A Session

The discussion primarily focused on university rankings. Mr. Hayashi said that the Japanese Government examines these rankings and works to improve both its universities' strengths as well as weaknesses. Dr. Guzzella stated that rankings are here to stay, but we should not allow them to change the souls of universities. Dr. Yamagiwa said that university rankings ought to promote innovative activities by researchers, but sometimes they do not. Dr. Maex conducted a poll of the audience to see if the participants thought rankings are helpful. One participant said that rankings can help spur interdisciplinary approaches, and universities should form their own assessment of the various rankings. Mr. Lim said that the rankings do not always provide the full picture because each university has its own nature and some are not entirely research-focused.

In response to a participant, Mr. Lim shared that Singapore had first implemented the flipped classroom model in a new institution, which had produced extraordinary results, before rolling it out to the existing universities.

Another participant returned to the topic of rankings, pointing out that government funding is sometimes linked to rankings. Mr. Lim stated that Singapore's framework looks at various aspects, including the goals and nature of the university. He shared that Singapore does not determine funding based on private sector rankings, and Mr. Hayashi agreed that this was essential. However, Mr. Hayashi noted that rankings can affect student decisions on which university to enter, which leads to other effects. In response to a question about creating better rankings, Dr. Yamagiwa emphasized the importance of university autonomy, and maintaining the freedom of individual departments to assess and select researchers regardless of rankings.

Another participant discussed promoting collaboration to help developing countries, as well as transferring knowledge on an international scale but at the level of individual scholars. An additional participant asserted that universities have become detached from the conversation about the future of society, and that universities must be brought back into that conversation to encourage investment in universities and corresponding societal success. Mr. Hayashi said that the topic of universities includes diverse aspects, but the benefits to society should be emphasized such as educational material available to the public. Mr. Guzzella stated that academics have neglected dialogue with the public, and should better emphasize the role of universities. Mr. Hayashi said that social science, science, and technology are intertwined. It is important to think about the kind of society we need to prepare for new technology and also to recognize that technology is researched for the benefit of society.

Science, Technology and Education in Digitalized Society

[Chair]

Gruss, Peter, President and CEO, Okinawa Institute of Science and Technology Graduate University (OIST), JAPAN; former President, Max Planck Society for the Advancement of Science, GERMANY

[Speakers]

Arthur, Michael, President and Provost, University College London (UCL), U.K.
Matsumoto, Hiroshi, President, RIKEN, JAPAN
Thompson, Hugh, Chief Technology Officer, Symantec Corporation, U.S.A.
Sato, Yoshiaki, Senior Vice President, Science and Core Technology Laboratory Group, Nippon Telegraph and Telephone Corporation, NTT, JAPAN

Opening Remarks

Dr. Peter Gruss began by stating that the world is at the brink of the fourth industrial revolution. The technologies that are available or being developed will fundamentally change people's lives and this revolution will be unlike anything humankind has experienced before. One of the key drivers of this transformation is digitalization, which pervades every aspect of our lives.

Chair: Gruss, Peter

The speed of scientific discovery has also accelerated. Digital technologies have made research more efficient, enabled the storage and sharing of data, and facilitated the analysis of huge amounts of data.

Digitalization has also changed education. Now students can access materials from leading universities around the world. Digitalization has also influenced what kind of educational content is needed. Educational curriculums must adapt to societal needs.
Cyber security, societal impact, changes in education are only some of the many consequences of digitalization. In addition, manufacturing is becoming increasingly automated, and many jobs that exist in this sector will eventually become automated. It is also important to establish an ecosystem that allows entrepreneurs to test new technologies.

Dr. Michael Arthur spoke about digitalization and education. University College London (UCL) has developed a strategy for the next 20 years in which it aims to foster graduates with clear independent thinking skills, who understand that knowledge changes over time, and are problem solvers, team workers, and good communicators.

The strategy aims to respond to the educational and societal needs of the digital age. UCL will offer not only physical spaces for education, but also digital spaces. UCL aims to prepare its students to be learners and good citizens in the digital age.

UCL is also engaged in research and development to enhance education. It will provide digital infrastructure to connect students with each other, staff, and external networks to support interdisciplinary educations. UCL aims to enhance the digital experience of students and provide world-class tools and support for teaching and support staff. UCL calls this approach the "UCL Connected Curriculum," and believes it can develop even more deeply inquiring minds.
Despite rapid advances in artificial intelligence and related technologies, such technologies will never replace human educators. Humans excel at nurturing common sense, imagination, and compassion, whereas computers excel at finding knowledge, computation, and pattern recognition.

Dr. Hiroshi Matsumoto discussed how digitalization has made enormous contributions to science. At the same time, science must adapt to the digitalization of society. The digitalization has created huge amounts of data and it is difficult to tell which data is useful and which is not.

RIKEN is engaged in three initiatives in this regard. First, it is sorting data to identify what can be shared and analyzed, and building a platform to harmonize the structures of data from different institutions to make them. Second, RIKEN is ensuring the quality of newly-generated experimental data by developing a robot experiment system that will free human workers from repetitive tasks and allow them to focus on intellectual tasks. Third it is developing tools to make data analysis more efficient and fast using artificial intelligence.

Finally, philosophy in digital society is important. Society must think about what has been lost as a result of digitalization and the dark side of science. We must ensure that people working in areas that directly impact people's lives, such as medicine and research, do not lose their sense of humanity.

Dr. Hugh Thompson began by sharing an anecdote of an experience he had while on a flight in which a bird became trapped on the plane. When relaying the story to a person who was in the security field and one that was not, the layperson reacted by inquiring about the wellbeing of the bird, whereas the security professional realized that if a bird could get on the plane undetected, someone could make a mechanical bird carrying explosives and fly it onto the plane.

This anecdote illustrates how people are not naturally wired to think about risk, especially not in relation to new technologies. In this age of digitalization and the creation of huge amounts of data, it is important to not only think about how such data can be used, but also what weaknesses it may have.

Dr. Yoshiaki Sato spoke about how smartphones and connected devices have changed our lives, and the activities of NTT. NTT believes collaborative R&D between different companies is essential. There are two types of industries in society. Industries that have used digital networks and those that have not. Companies in these different industries should cooperate to generate innovation.

As an example, NTT has been collaborating with Toray to develop digital T-shirts that can measure one's heart rate. This collaboration was successful because both sides had knowledge that the other did not have but needed. Toray needed knowledge about digital networks and NTT needed knowledge about textiles. Similarly, NTT is working with Toyota to develop connected cars, in which NTT benefits from Toyota's automotive knowledge and Toyota benefits from NTT's digital network knowledge.

Through these and other activities, NTT envisions and hopes to achieve a society in which everything is connected to the network.

Discussions

Dr. Gruss asked if the digitalization of society was creating winners or losers.

Dr. Thompson believed that one side effect of the digitalization of society was that, individual people are now more knowable from a distance than they were in the past. This new reality needs to be further studied from psychological and anthropological perspectives. If society is not careful the average citizen could be a loser in that he or she would be more susceptible to deception.

Dr. Matsumoto thought that citizens can be both winners and losers. With information now being available at the push of a button, people could end up being more knowledgeable but less thoughtful.

Dr. Arthur pointed out that while a lot more knowledge may be available to people, it is not necessarily always useful knowledge.

Dr. Gruss asked what the future of society and cities would entail.

Dr. Sato believed that many new machine interfaces will be generated and embedded into society. However, the landscape of cities and rooms will remain the same, except that many more sensors will be incorporated into this landscape.

Dr. Gruss asked if it would ever be possible to have a secure dataset again and how such data can be protected.

Dr. Thompson suggested that society is only beginning to understand the properties of such large data sets being available. One of the challenges is how to ascertain the veracity of a piece of data. Lessons could be learned from the proliferation of Bitcoin and the use of block chain technologies to ensure the credibility of online transactions. Furthermore, there is surely an increasingly large role for sociologists, anthropologists and psychologists in the security field.

Dr. Gruss asked Dr. Matsumoto about the work of RIKEN's new artificial intelligence institute.

Dr. Matsumoto explained that RIKEN's new center has a group of mathematicians who are trying to develop a deeper understanding of the mechanisms of deep learning and also a group that identifies future problems that could arise from artificial intelligence from an ethical and philosophical standpoint.

Dr. Gruss asked why universities are necessary in an age of virtual realities and augmented realities.

Dr. Arthur argued that universities provide background expertise and teach the younger generation to use their knowledge, their emotional intelligence, and their compassion.

Q&A Session

The first question from the audience concerned fears over the misuse of artificial intelligence, and whether people were primarily concerned with the technology or human beings.

Dr. Matsumoto believed that the fear was of human beings, because it is the human beings who use or misuse the technology.
Dr. Thompson said that artificial intelligence is merely a tool, albeit a very powerful one, that enables people or companies to achieve their objectives. The danger is that there are many

actions that may be mathematically correct but morally incorrect. It is important for society to rethink safety and how it teaches ethics.

Another participant commented about the importance of educating the public about the potential adverse consequences of the digitalization of society.

Next, a member of the audience pointed out that different generations had different levels of comfort with risk.

Dr. Matsumoto suggested that new technologies are always viewed with a sense of risk.

Dr. Thompson believed it is necessary to equip people with the ability to assess and deal appropriately with new risks.

Another member of the audience pointed out the ability of technology to be abused not only by individual actors, but also state actors. He also noted that, unlike physical crime, when one's data has been compromised, it is not clear that a crime has occurred.

Dr. Thompson stated that there needs to be a better understanding of how data can be used as a tool to attack society. This is a field that is ripe for intellectual research.

In closing, Dr. Gruss stated that the underlying message of the session is that technology should be developed and used for the best of society, rather than the worst, and to achieve this, efforts to engage and educate citizens are paramount.

Population and Resources

[Chair]

Komiyama, Hiroshi, Chairman of the Institute, Mitsubishi Research Institute, Inc., JAPAN

[Speakers]

Abdul Hamid, Zakri, Science Advisor to the Prime Minister of Malaysia, Office of the Science Advisor, Malaysian Government, MALAYSIA

Kaneko, Ryuichi, Deputy Director-General, National Institute of Population and Social Security Research, JAPAN

Lutz, Wolfgang, Founding Director, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), AUSTRIA

Pandor, Grace Naledi, Minister, Ministry of Science and Technology, SOUTH AFRICA

Opening Remarks

Dr. Hiroshi Komiyama began by stating that population is a fundamental constraint on the sustainability of humanity, and the burden on resources and the environment depends on population and per capita consumption. However, population explosion will not occur due to continued fertility decline around the world. Nevertheless, the population will increase for quite a while with increases in life expectancy.

Chair: Komiyama, Hiroshi

Dr. Zakri Abdul Hamid stated that the percentage of the population with a decent standard of living is higher than ever, but that there is a large gap between the rich and the poor. Before the era of explosive population growth ends by 2050, the world will have more than 9 billion people, and the challenges faced will be enormous given the limited resources and vulnerable environment. The world is witnessing already the impact of climate change on natural systems. This is translated into increased frequency and severity of natural disasters, which has led to more disasters due to population growth and patterns of economic growth. Since 2008, for

the first time in human history, more people are living in cities than the countryside, causing urban sprawl. Now more than half of the world's population live in cities. Cities cover no more than 2% of the earth's surface but are responsible for two-thirds of global energy consumption. The need for food, space and raw materials has resulted in the destruction of biodiversity and ecosystem. In the coming decades it is likely that this trend will continue with more losses expected in resources and assets. The countries least responsible for climate change have limited capacity and resources to cope with the consequences. All solutions require a generous adjustment between the haves and have-nots. In order to cope with these issues, the global community needs to develop a common understanding of the problems and the technology to manage and overcome them. The SDGs are a good start but they need to be translated into actions at the local and national levels.

Dr. Ryuichi Kaneko stated that while the destructive impacts of population growth on resources have been emphasized, population changes not only in size but also in quality. Population quality concerns: 1) health, which is fundamental in human capital; and 2) education. Demographers measure the healthiness of the population by means of life expectancy. According to the latest United Nations estimates, global life expectancy at birth has been extended by 25 years since the 1950s. In the less developed region, the probability of children reaching adulthood has risen to 94% for the same period. These improvements demonstrate that efficacy of educational investment has greatly increased. On the other hand, the most serious challenge in the 21st century is global population aging. Although many people perceive that longer lifespan or longevity is the prime cause of population aging, longevity and health improvement are the only hopes for countering population aging. Today's average 65 year old person is 9.5 years younger than the equivalent person in the 1950s. By the end of this century, this difference will increase to 17 years. If this rejuvenation effect is taken into consideration, the proportion of the elderly aged over 65 at the end of the century will be equivalent to only 8.4%, similar to the current level, instead of 22% in the face value. Promotion of health and longevity may thus have a counter effect on population aging. Yet in the current social system these benefits of the rejuvenation effect cannot be appreciated. Innovative reforms are needed on the social side in addition to those in science and technology.

Dr. Wolfgang Lutz stated that demography is a serious scientific discipline but that it deals with controversial aspects such as birth, death, sex, contraception, abortion and international migration, which are subject to political controversy. The discussion is often confused by the fact that there are opposing challenges in different parts of the world. Recently

the international modelling community developed population scenarios based on shared socioeconomic pathways (SSP). If the education and health SDGs are implemented, the world population may only increase to 8.6 billion but this is optimistic. There is a huge range of uncertainty in population estimates. Sub-Saharan Africa has 1 billion people now and this number may reach to 3 to 5 billion people. Women's education is the single most important factor for fewer children. Education is also key for dealing with population aging. For both developed and developing countries, focus on national human resource management should be the population policy of the 21st century.

Ms. Grace Naledi Pandor explained that South Africa has a demographic dividend where the majority of the population is young people. However, this does not translate into benefit because the majority of the young people are poor, with no education and no access to skills, training or employment opportunities. One solution is to make far more effective use of education and also to ensure that countries invest more in science, technology and innovation. One of the other features of the growth in population has been massive urban sprawl, and urban development needs to be addressed in a decisive fashion. Rural development also requires attention, with much of the land remaining unproductive, not being utilized to enhance food security and not contributing to human development. More research is also needed on climate change in Africa because the ravages of climate change are impacting that part of the world more than is understood. Africa has the greatest mineral resources available to the world but it is not a beneficiary of those resources, making it essential to invest in science, technology and innovation related to mineral extraction. The focus on education should be on women and girls. Vocational education and training are also needed. One of the challenges is addressing how to end inequality, how to transform population changes into advantages for the world and how the world's resources and intellectual resources are used in order to effect changes.

Discussion

Dr. Komiyama asked if population aging decreases resource consumption per capita.

Dr. Lutz commented that more education leads to better general empowerment, which is an important driver of economic growth. Education adds to wealth and income and tends to increase consumption, while at a given level of income the more educated people tend to be more flexible and shift to more environmentally-friendly behavior.

Dr. Abdul Hamid responded that education would result in citizens who are more reasonable and can appreciate the vulnerability. He also urged that the STS *forum* recommends practical approaches so that the discussion does not become esoteric.

Ms. Pandor was unsure if population aging decreases resource consumption but noted that it changes the nature of resource consumption. She underscored that people should seek education not to derive wealth but to use resources to improve the world, adding that there is sufficient wealth to be shared more equitably.

Dr. Komiyama asked if internet education improves education

Ms. Pandor believed that it opens up opportunities but was not entirely certain based on people's use of social media.

Dr. Komiyama asked which crucial resource is most in danger.

Ms. Pandor said more attention needs to be paid to human resources and food.
Dr. Komiyama asked if genetically modified organisms (GMOs) may be a potential solution and whether she was referring to the sustainability of food production.

Ms. Pandor responded that it is about sustainability as well as ensuring that GMOs are not over-utilized as its potential problems are still unclear.

Dr. Lutz agreed that food is essential and that human resources are in short demand. He wondered whether AI can substitute human resources for certain activities.

Dr. Abdul Hamid noted that in 2005 it was found that 60% of ecosystem services were being depleted due to the modern lifestyle of human consumption. He said this will be problematic as the population continues to rise. He agreed that their survival must take cognizance of that, stating that there are many solutions and what is lacking is action and political will.

Q&A Session

A participant noted the difficulties of matching expectations and reality and how expectations may have to be lowered to meet the needs of society.

A participant asked how migration can be governed.

Due to time constraints, the session was adjourned without the speakers responding to the questions.

Science and Technology in Business and Finance

[Chair]

Priyanto, Unggul, Chairman, Agency for the Assessment and Application of Technology (BPPT), INDONESIA

[Speakers]

Colombani, Pascal, Honorary Chairman of the Board of Directors, VALEO SA; Vice-Chairman; Special Envoy of the President of the French Republic for the French-South African Nuclear Partnership, French National Research Strategy Council: French Ministry of Foreign Affairs, FRANCE

Gopalakrishnan, S. Kris, Chairman, Axilor Ventures, INDIA

Higashi, Tetsuro, Corporate Advisor, Corporate Director, Tokyo Electron Limited, JAPAN

Gantsho, Mandla, CEO, Africa Rising Capital (Pty) Ltd.; Chairman, Sasol Limited; Chairman, Impala Platinum Holdings Limited; Chairman, Ithala Development Finance Corporation Ltd., SOUTH AFRICA

Opening Remarks

Dr. Unggul Priyanto began by stating that science and technology have brought changes to all aspects of our lives, and the competitiveness of economies increasingly depends on capabilities of leveraging scientific and technological advances. Science and technology, especially digital technology, have transformed businesses and the financial sector with the availability of huge computing power, artificial intelligence, and big data. Fintech is one area that is making huge strides, especially for inclusive finance, as currently 2.5 billion adults still lack access to financial services.

Chair: Priyanto, Unggul

Digital technology has also given rise to concerns about cybersecurity necessary to counter cyberattacks. In addition, the level of technology differs by country, with developing countries seeking to leapfrog the absence of a traditional "industrial revolution." Countries and businesses have found that they must invest in science and technology or someone else will.

Dr. Pascal Colombani pointed out the need to develop knowledge that translate into economic benefits while managing risk. New technologies impact our lives in a way we could not have conceived previously. We are witnessing a revolution based on transformational changes with ecological and energy considerations, the digital revolution with vast amounts of data, bioengineering, and the use of new nanoscale materials. Innovation processes are changing rapidly, as huge computing power, huge databases coupled with artificial intelligence, product or services development through simulation, and rapid prototyping spread in all areas. In addition, the pace and breadth of technology is such that even the largest, most profitable companies need open innovation processes.

Open innovation's key aspects include outstanding upstream academic participation, shared vision between partners, downstream industrial capabilities, and access to capital. To illustrate the statement from the CEO of Volkswagen that in the future we will be connected, autonomous, shared and electrified, Dr . Colombani then described relevant examples of partnerships developed by Valeo, a leading automotive component supplier, to satisfy this new goal of the automotive manufacturers.

Dr. Colombani concluded by stressing the need for added competencies required by the importance of data management or bioengineering, and outlined the role that universities and education systems should play to provide for them.

Mr. S. Kris Gopalakrishnan explained that because hundreds of millions of Indians have smartphones, the Indian government started a biometric ID system initiative called Aadhaar that already has over one billion users and seeks to leverage the advantages posed by so many people with smartphones. The initiative has many applications, such as all people with an ID receiving a bank account. Such innovation can transform societies.

Mr. Gopalakrishnan outlined several issues in the age of ubiquitous smartphones and social media. Technology means that all voices are now heard, resulting in increases of verbal threats. We are now being drowned with data, and we need to talk about it. He also mentioned the Equifax leak, which raises the significant point that we need to have a policy to determine who owns data.

Mr. Tetsuro Higashi said that for decades, scaling enabled devices to become faster and smaller, all while prices fell. However, now we are seeing increasingly accelerated changes, and thousands of devices are being connected and software is being developed to take advantage of these networks. Now, artificial systems and deep learning are starting to overtake the capabilities of human beings, and are being deployed to reduce human workplace inefficiencies. This means that our lifestyles will undergo changes.

As everything becomes connected, safety and security are paramount but we are still struggling to maintain them. If we cannot control our "not-so-smart devices" now, such as PCs, then how can we control devices that have become sentient? A few hackers can create havoc today, but imagine an army of AI hackers. Mr. Higashi suggested that we could have a guardian AI device sanctioned by an international body.

In addition, energy requirements for the future are expected to outpace total energy production by 2035. Energy production can lead to natural resource depletion. To solve this, the semiconductor industry has been driving innovation, with Tokyo Electron Limited devoting billions of yen to it. Governing bodies of the world need to gather to think about technology management, and perhaps decide on a security foundation system. Mr. Higashi finally advocated IA (intelligent augmentation) instead of AI, stressing that we should augment our lives with technology but not let AI run our lives.

Mr. Mandla Gantsho shared an African perspective on driving prosperity. Africa has long failed to embrace science and technology, which would help leverage the continent's significant natural resources. Opportunities posed by science and technology can help Africa leapfrog toward progress, including financial services, energy, and mineral resources. For financial services, recent innovation has revolutionized the sector, including internet banking. This has lowered costs and promoted financial inclusion, helping even the poorest people to access services. Telecommunication capabilities, with their ensuing benefits, are expected to double for years. However, this has also exposed people to risks like cybercrime.

Reliable electricity is also a problem for Africa that is holding back development, which is ironic because Africa is actually rich with natural resources. Solar power represents a cost-effective, reliable solution. Africa is also rich with mineral resources like cobalt and platinum group metals (PGMs). Development of technology partnerships is important to leverage these metal resources.

Mr. Gantsho then highlighted partnerships with Japanese companies in Africa, including for PGMs. PGMs especially represent opportunities for automobile initiatives, and there are partnerships with Toyota and other Japanese automobile companies to reduce emissions, and other partnerships have helped develop uses for PGMs. Africa will continue to develop innovation and partnerships to leverage its natural resources.

Q&A Session

There was a question about financing technology in the future, especially in developing countries. Mr. Gopalakrishnan stated that when innovation comes to market, certain jobs often become redundant as technology displaces workers. We have to look into new future needs and help people transfer into new job categories that include filtering bad data and identifying problems with machines. Mr. Gantsho stated that there are tradeoffs in development. In old models of banking, there was a need for brick and mortar branches, but now with mobile banking these branches are decreasing. However, mobile banking has enabled even lower income societies to access banking services, which allows them to access capital and pursue entrepreneurship and creating new businesses.

Another question was about the paradox that evolution in technology is posing, namely that problems of safety often come from the human side, leading to a need to invest further in social science. Mr. Higashi said that he always warns about the consequences of AI, including the human element that can fail to control it. We must have protection systems created through global discussion. Mr. Gopalakrishnan stated that technology is a tool, and it is up to humans to use or misuse it.

Another question was on inclusiveness of people who have been left behind by the entrepreneurs who have been able to take off with new technology. Dr. Colombani stated that humans have always sought growth, but now we understand that there must be fundamental priorities, and the use of technology should also alleviate differences between rich and poor. Politicians especially should look at wealth disparities between people as well as countries. Mr. Gopalakrishnan emphasized that we must help people attain new skills.

A further question was about uncertainty in how AI will behave with certain inputs. How should we address this problem, and who exactly should address it? Mr. Gopalakrishnan pointed out that over the years we have made automobiles increasingly safe and reduced accidents. The same is true of AI, which must be fine-tuned. One problem is that data is biased, and we must make sure it is appropriate for use. Mr. Higashi said that the STS *forum* includes leaders from academia, politics, and technical areas, and is an excellent opportunity to discuss risks. He said he looked forward to the next year of the STS *forum* to discuss the risks posed by the participant. Mr. Gantsho said that there needs to be a proactive regulatory environment between various players to prevent potentially harmful technologies from being deployed before they are properly vetted. Mr. Colombani stated that subjectivity and safety of data are important to examine, and something regulators have not been addressing yet.

The final question was about adapting business processes to increase profitability in this age of revolution. Mr. Gopalakrishnan said that business processes must incorporate analysis of innovation and technology and identify necessary changes. An example of business process transformation is Amazon, which, having mastered online business, is now opening physical locations. Mr. Gantsho said that innovation must answer to customers, and needs to be spearheaded by people who are customer-facing rather than those in the back offices.

Delivering Health Care to the World

[Chair]
Roberts, Richard J., Chief Scientific Officer, New England Biolabs, U.S.A.
[Nobel Laureate 1993]

[Speakers]
Hacker, Jörg, President, German Academy of Sciences Leopoldina, GERMANY
Narasimhan, Vas, Global Head, Drug Development and Chief Medical Officer, Novartis International AG, SWITZERLAND
Weber, Christophe, President & CEO, Takeda Pharmaceutical Company Limited, JAPAN
Hayashizaki, Yoshihide, Advisor to the President & Program Director, RIKEN, JAPAN

Opening Remarks

Dr. Richard J. Roberts introduced the topics of discussion for the session. These include how to provide healthcare to all people, not only in developed countries, but also developing countries, how to tackle the challenge of aging population, the potential of and challenges in drug development, and the role GMO foods can play in tackling the problem of hunger.

Chair: Roberts, Richard J.

Dr. Jörg Hacker stated that the world faces many challenges that affect global health, making global health systems and universal health coverage a critical issue. Not only communicable disease issues but also non-communicable diseases have become a growing concern.

Global concern is defined as those health issues that transcend national boundaries and require the attention of global actors. The world needs transparent and holistic approaches for better global solutions that incorporate multiple stakeholders. Enhancement of education and research will also be important to protecting and improving health.

Scientific academies play a vital role in supporting scientific progress, fostering collaboration, and promoting public discourse. Furthermore, in recent years, they have been making their voices heard in international political fora, including the G7 and G20 frameworks, and making scientific recommendations to leading global policymakers. This is essential for generating the political will needed to take action across national borders to improve global health.

Dr. Vas Narasimhan championed the importance of organically forming networks of collaboration for tackling increasingly complex health care issues. He shared examples of how Novartis had leveraged the power of such networks, including in tackling malaria in Gabon, in conducting the first global clinical trial for cell-based therapy for cancer, and in carrying out genomic screening for Alzheimer's disease.

In all the above cases, the networks were not formed in a top-down manner, but organically, by individuals who take shared pride in trying to solve the global health issues we face. Such collaboration is an important first step, and in the long-term we will need to leverage the shared neural network of the world to develop better medicines and to share them with people around the world.

Dr. Christophe Weber began by expressing his optimism regarding the continued discovery of new medicines and treatments, thanks to advances in research, and increasing collaboration between companies and across industry, government, and academia.

Dr. Weber then addressed the issue of aging populations and the resulting health problems this produces. Many countries' health care systems were designed several decades ago reliant on emerging new populations. The demographic pyramid is now the inverse of what it was then. Moving forward, the challenge is to design a health care system that is capable of financing the innovations needed to support the aging population. There are still many open questions related to this that need to be answered.

Dr. Yoshihide Hayashizaki spoke about the rising costs of drug development. While innovation has the power to create new drugs, a more urgent priority is to generate innovation that reduces the costs of drug development, which have risen exponentially over the past decades. These rising costs of developing drugs are reflected in the high prices of drugs.

Japan has a universal health care system, and such expensive drugs endanger the sustainability of that system. At the same time, reducing the profits of pharmaceutical companies would reduce the incentive to generate essential innovation. These conflicting interests present a dilemma.

A recent report suggested that infections by multiple drug-resistant bacteria will become the leading cause of death, overtaking cancer, by 2050, and yet no new antibiotics have entered the market since 1990, because of their low profitability, which is due to their short administration period, and guidelines that prohibit their use as the first indication for bacterial infection out of fears of creating drug-resistant bacteria. One solution that the Japanese government is proposing is to accelerate the approval process to speed up the introduction of drugs to market, while of course maintaining the necessary safety standards.

Dr. Roberts reminded the audience that the needs of people in the developing world are very different from those of the developed world. In particular, a primary concern in developing countries is to ensure people have enough food that is sufficiently nutritious.

However, an anti-GMO movement in Europe, spurred on by Greenpeace, is hindering efforts to tackle this problem. It is not right for people in a developed country to tell people in a developing country to not use the best means that they have to address one of the biggest issues they face.

In such cases, when science is denigrated, scientists try to defend themselves and explain the issue. However, this is not working. It has become an emotional issue. In response, Dr. Roberts has started a movement, recruiting 121 Nobel laureates, to compose and send a letter to Greenpeace and the United Nations, telling Greenpeace to stop these activities, which are based on falsified science.

One of the aims of STS *forum* is to bring emerging biotechnologies to all parts of society. If the leading societies follow through, engage political leaders, and convince them of the safety of GMO technology, then they will contribute to realizing the vision of STS *forum*.

Discussion

Dr. Roberts asked the speakers for their thoughts on mosquito-borne diseases and eradicating mosquitos using gene-based approaches.

Dr. Narasimhan was positive that these approaches could be viable.

Dr. Hacker was also optimistic but reminded that more scientific data is still needed.

Dr. Weber expressed his optimism as well, but believed that it will be important to hold wider public discourse to foster understanding for gene-editing technologies.

Dr. Hayashizaki pointed out that in addition, the distribution of mosquito-borne diseases is changing, and there is a need for technologies or methods for changing mosquito vectors. He also commented on the importance of nutrition and access to water, and highlighted the need to consider these alongside mosquito-borne diseases, as issues affecting developing countries.

Dr. Narasimhan believed that it was just a matter of time before autologous technologies for eradicating mosquito-bearing diseases could be realized. What is important is to start ethical discussions around such technologies.
Dr. Roberts agreed and cited the importance of holding broad discussions that also include the most-affected parties. He then raised the significance of discussing the issue of end-of-life decisions, especially as life expectancies are increasing and medicine advances.

Dr. Hacker concurred with the need for discussion across a wide range of society, including religious institutions, not only at the national level but also internationally, and hailed STS *forum* as an excellent venue for such international discussions.

Dr. Narasimhan believed that at times there is an overemphasis on prolonging life over maintaining quality of life.

Dr. Hayashizaki explained that Japan is facing an aging society and declining population. In such circumstances, it is important to think about the overall care of the elderly and their happiness. Governments should provide not only social support for the elderly but also ways in which they can contribute to society.

Dr. Roberts also raised the question of individual choice in end-of-life decisions, and the importance of debating this while the individual is still capable of making reasoned and informed decisions. He also noted the need to give patients more credit and facilitating greater participation of patients in developing health care solutions.

Dr. Weber explained that Takeda tries to bring the experience and knowhow of patients into the company. He said it used to focus on the doctor's experience. There will be far more patient data in the future and this will bring the patient experience much more into research.

Dr. Hacker shared an anecdote of how the views of patients can help influence politicians of the merits of potentially controversial medical technologies.

Dr. Narasimhan was optimistic about the possibility to create personalized medicine with big data.

Dr. Roberts believed that the anti-GMO movement threatens scientific research efforts to tackle health issues and hunger. Politicians should be aware that if hunger issues are not dealt with, it could exacerbate issues related to the mass migration of people.

Dr. Hayashizaki shared a case in which GMO foods were able to address food shortages and also improve nutrition in Rwanda. He emphasized that GMO foods are safe and important.

Dr. Roberts commented on the promising results seen with golden rice, which was previously vehemently criticized by Greenpeace. He then highlighted the potential insights that could be found from mapping the bacterial microbiome.

Dr. Narasimhan agreed that this field holds great potential but felt that more research is needed before viable medical applications can be found.

Dr. Hacker agreed that this is one of the most exciting new fields in biology.

Dr. Weber concurred and also pointed out that the emergence of such research is a sign that the scientific community is no longer afraid of complexity and dealing with huge sets of data, which are essential for such research.

Dr. Hayashizaki believed that such research can advance efforts to develop drugs for anti-microbial resistance.

Finally, Dr. Roberts reiterated the importance of holding public discourse, with a wide range of actors, and not leaving it to a small group of intellectuals to decide for others what is best for society.

Development and Sustainability for the Future of Humankind

His Imperial Highness the Crown Prince of Japan
Her Imperial Highness the Crown Princess of Japan

[Chair]
Wiesel, Torsten Nils, President Emeritus, The Rockefeller University, U.S.A. [Nobel Laureate 1981]

[Speakers]
Yamanaka, Shinya, Director and Professor, Center for iPS Cell Research and Application, Kyoto University, JAPAN [Nobel Laureate 2012]
Kumar, Ashwani, Senior Advocate Supreme Court; former Union Minister of Law & Justice & Member of Parliament, India, Rajya Sabha (India), INDIA
McNutt, Marcia, President, National Academy of Sciences, U.S.A.
Omi, Koji, Founder and Chairman, Science and Technology in Society *forum* (STS *forum*); former Minister of Finance, JAPAN

Chair: Wiesel, Torsten Nils

Opening Remarks

Dr. Torsten Nils Wiesel believed that addressing challenges faced by mankind is a formidable task. Japan rose from the ashes of World War II to become one of the foremost technological and industrial nations in the world and a leader in science. This leadership was due to the sustained and generous support by the Japanese government.

Dr. Wiesel mentioned his involvement in the Human Science Frontier Program and the Okinawa Institute of Science and Technology Graduate University (OIST). They are both international and visionary and enable students and scientists from around the world to engage independently in interdisciplinary science.


Their Imperial Highnesses the Crown Prince and Crown Princess of Japan

Today there is a convergence of all the fields of natural science. To generate innovation, it is therefore vital to create opportunities for students and faculty to be engaged with multiple disciplines.

In fact, most advances in science and technology have been generated by human imagination and curiosity. It is thus important to ensure academic freedom and allow researchers to follow through on their curiosity unhampered.

Finally, Dr. Wiesel expressed his hope that, today, when political rhetoric is rife with fear and threats, political leaders should lead us to more positive goals and invest more seriously in education, science, and the arts.

Keynote Address

His Imperial Highness the Crown Prince of Japan delivered a keynote address.

“Excellencies,
Distinguished participants,
Ladies and Gentlemen,

It is my great pleasure to see that the 14th Annual Meeting of the Science and Technology in Society *forum*, the STS *forum*, has been successfully concluded with fruitful discussions over the past three days among esteemed participants from all over the world.

His Imperial Highness the Crown Prince of Japan

This is the fifth time I have attended the STS *forum* since its founding in 2004. It is of great significance that the STS *forum* has held lively discussions over the last 13 years on various issues related to the so-called "lights and shadows" of science and technology, as well as sustainability for the future of humankind. I would like to express my deep respect for all the efforts made by those dedicated to organizing this forum as well as those who participated in the previous forums.

This forum covers state-of-the-art science and technology issues like life sciences including genome engineering, the internet, and artificial intelligence, all of which have been rapidly progressing and will lead to important innovations in future society. Simultaneously it also touches upon various issues arising from their advancement and development. It is indispensable to discuss innovation not only from positive aspects, but also from various other aspects. I, together with the Crown Princess, feel very encouraged to hear that young people from many countries, who might take the lead in the society of the future, were greatly stimulated by their dialogue with Nobel Laureates.

In thinking of the future of humankind, it is necessary to discuss issues like climate change, energy, food and water from the viewpoint of not only 20 to 30 years in the future but also from a longer-term perspective. It is also crucial that leaders of governments, industries and academia should get together with specialists in science and technology, and discuss these global issues as their own problem by creating an inter-disciplinary network.

In conclusion, I would like to renew my sincere wishes that the STS *forum*, held here in Kyoto every year will continue concentrating the wisdom of world leaders to discuss the effective use of science and technology for the future of the earth and the sustainable development of humankind, and will further contribute to the future of humanity.
Thank you very much for your kind attention."

Speakers' Remarks

Yamanaka, Shinya

Dr. Shinya Yamanaka began by explaining his career path, how his father inspired him to become a doctor, and how, subsequently, his father's passing, due to hepatitis, inspired him to become a medical researcher.

Science and medical research has the power to overcome diseases. For example, hepatitis, which, at the time of Dr. Yamanaka's father's passing, was incurable, can now be managed with a daily tablet.

Dr. Yamanaka also shared a case in which a young boy suffered from abnormal bone growth in his muscles. Dr. Yamanaka's colleagues generated iPS cell-derived bone cells from the boy's skin cells to understand the disease mechanism and search drugs for it. A clinical trial for a potential treatment is about to begin.

Although science has the power to overcome diseases, the development of treatments takes much time and funding. Furthermore, treatments are often extremely expensive. To ensure the utmost efficacy and benefits of medical treatments, collaboration is essential, not only among scientists but also with the involvement of philanthropists and policymakers.

It is possible for science and technology to find solutions to disease and other challenges, but we must all work together, and act as quickly as possible. STS *forum* is an indispensable venue for promoting such cooperation and action.

Dr. Ashwani Kumar spoke about the "shadows" of science and technology. We are witnessing technological advancements at an unprecedented pace. Nevertheless, we still face the daunting challenges of widespread poverty, or life lost to causes such as diseases, malnutrition, and terrorism. Why is this still the case, despite these technological advances? That is the key question we must ask ourselves.

Kumar, Ashwani

McNutt, Marcia

Somewhere in the application of the benefits of science and technology, we have missed the core point. There is widespread disparity in the world. This raises many questions. How do we humanize society, at a time of extensive single-minded pursuit of economic gain? Have we confused standards of life with standard of living? Are we comfortable with increasingly compromised privacy in exchange for the advancement of an information society? There is no questioning the value of science and technology but we must direct science and technology in the right direction and do more to address the "shadows" they create.

Technological optimism does not negate the need for fundamental societal change and shifts for the better. Technological progress cannot come at the cost of humanity's dignity. Our quest for progress must be anchored in equity and compassion.

It is our duty to ensure that technologies advancement is not at the cost of "humanity's rightful dignity and moral integrity". In scripting the history of our age, we must continually remind ourselves, lest we forget that "man is the measure of all things". The challenge is to humanize society and address ourselves to the need of making ethical choices consistent with the sanctity of fundamental human freedoms. It is also necessary to remember that machines cannot by themselves generate compassion and empathy that must define a caring world. We must continually ask ourselves whether we have adequately prepared large populations for the disruptive changes resulting from transformational technological changes.

Dr. Marcia McNutt spoke about the issues of sustainable development. Sustainability requires that humankind take a long-term view. However, it is not possible to take a long-term view if one cannot deal with the immediate basic needs of today. The pursuit of sustainability begins with tackling inequalities.

Innovation has the potential to change the calculus and create win-win situations. Advances in science and technology can create solutions for feeding more people or more affordable medical treatments. However, innovation requires more, and more diverse, innovators.

Omi, Koji

Innovators must be risk-takers, well-educated, and aware of the importance of sustainability. Innovators also need the support of those around them, so that they can forsake short-term gain for much greater long-term rewards.

Fostering a sustainable mindset begins with education. Educating women can stabilize and potentially double the income of households, which in turn would create opportunities for the next generation. There is no path to sustainable development without access to education for all, starting with education for women.

Chairman Koji Omi thanked the participants for their contributions and presented major themes from the 14th Annual Meeting of STS *forum*. The lack of solutions to environmental issues is a major challenge. Much of the global discussion of environmental issues are still too focused on the short-term. We must take a far longer-term view, extending many centuries into the future.

Using data and knowledge is important. Open innovation is founded on the unimpeded exchange of ideas and knowledge across different disciplines.

Tackling climate change is essential for achieving sustainable development. Energy solutions have a key role to play in this regard. Nuclear energy remains an important option, provided it is founded upon safety, security, and non-proliferation.

Advances in genome engineering and advanced medicine have the potential to greatly improve global health. However, medical treatments must be accessible to all. Furthermore, international cooperation is invaluable, as the fight against infectious disease is a global mission.

The digitalization of society can radically transform our lives. However, privacy and security issues must be addressed and deliberated by society as a whole.

Cooperation across government, industry, and academia is essential for achieving sustainable development. The participation of policymakers and business leaders is also essential. This year, STS *forum* launched a CEO meeting, in addition to its existing CTO meeting. Furthermore, STS *forum* recognizes the importance of future leaders and, this year, close to 140 young leaders from business and academic institutions participated in the Future Leaders Program, which included a special dialogue with 15 Nobel Laureates.

Finally, Chairman Omi said he looked forward to seeing the participants again in 2018 and asked them to encourage their colleagues to join as well. In closing, he expressed his hope that, together, the participants of STS *forum* could pave the way for future generations.

Concurrent Sessions

Key Messages from Concurrent Sessions

[Chair]

McKinnell, Henry A., Chairman, Moody's Corporation, U.S.A.

[Speakers]

Zacharia, Thomas, Director, Oak Ridge National Laboratory, U.S.A.

Wallberg, Harriet, Director General, Ministry of Health and Social Affairs; Professor of Physiology and former President, Karolinska Institutet, SWEDEN

Nelson, Donna J. Professor, Department of Chemistry and Biochemistry, University of Oklahoma; President, American Chemical Society (2016), U.S.A.

Falk, Jim, Honorary Professorial Fellow, Melbourne Sustainable Society Institute, University of Melbourne, AUSTRALIA

Hassan, Mohamed Hag Ali, Executive Director a.i., The World Academy of Sciences (TWAS), ITALY

Mazur, Eric, Balkanski Professor of Physics and Applied Physics and Dean of Applied Physics, Harvard University; President, The Optical Society, U.S.A.

Kitano, Hiroaki, President & CEO, Sony Computer Science Laboratories, Inc., JAPAN

Johnson, Ray O., Executive in Residence, Bessemer Venture Partners; Senior Vice President and Chief Technology Officer (ret), Lockheed Martin Corporation, U.S.A.

[Future Leaders]

Subrina, Samia, Associate Professor, Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology (BUET), BANGLADESH

Platt, Glenn, Research Program Director, Commonwealth Scientific and Industrial Research Organisation (CSIRO), AUSTRALIA

Opening Remarks

Dr. Henry A. McKinnel shared his key takeaways from the discussions at STS *forum* thus far. First, mankind is facing an inflection in history and we must prepare ourselves and future generations for a profoundly different world. Second, society may be overemphasizing short-term needs over long-term issues. Third, society must balance the management of risk with the continued pursuit of innovation.

Dr. McKinnel then presented a challenge to the audience. He urged participants to continue producing great science, but to use that science to contribute to knowledge and create products that benefit mankind.

Chair: McKinnell, Henry A.

Dr. Thomas Zacharia presented the key messages from the Energy and Environment concurrent sessions. Despite improvements in energy efficiency, growth of a global middle class will increase demand for oil and gas significantly. At the same time, the shale revolution is transforming the outlook for oil and gas. Air pollution is pushing many countries toward alternatives to fossil fuels. In addition, many automakers are focusing on electric vehicles. Nevertheless, transport and logistics systems will largely depend on oil products for some time to come. The oil and gas industry recognizes that it must transform itself and is embarking on efforts to do so.

Nuclear power will continue to play a vital role in reducing carbon emissions. A key issue will be making this sustainable source of power more accessible to less developed nations. Furthermore, there remain questions of safety, waste, non-proliferation, cost, efficiency, and common standards that should be addressed through international cooperation.

Renewable energy sources provide substantial benefits and, with continued development of the related science and technology, we can expect ever-greater deployment of these sources. Further development of smart grid systems and energy storage technologies is essential to full utilization of renewable energy.

There is no single optimal energy mix. Rather, the needs and capabilities of a particular country or region will drive its energy systems, and we must therefore continue to create innovations across a spectrum of sustainable energy options.

Next, Dr. Harriet Wallberg reported on the key messages from the Life Sciences concurrent sessions. Society is seeing fast development in technologies that are fostering more collaboration and opening up more possibilities for further advancement. At the same time more sophisticated regulation and great public participation is needed.

Zacharia, Thomas

Wallberg, Harriet

The impact of human activity on the environment is a major concern, especially with the growing human population. Humans give rise to burdens on eco-systems, which in turn adversely impacts our health. Combining clinical and basic sciences in research and education are critical for tackling these issues. Furthermore, data sharing offers huge potential, but also challenges such as privacy and security.

Advances in gene editing and engineering techniques continue to be made, that contribute to understanding and treating diseases. In this field, it is essential to distinguish between somatic and germ-line engineering. In particular, there are important ethical questions concerning the latter, and they should be debated by society as a whole.

Gene-based therapies are a new and promising field in advanced medicine. To advance medicine further, it is necessary to stratify people and patients. We must also provide affordable and accessible medicines to developing countries.

Discussing healthy lifespans rather than long lifespans is more meaningful. Aging populations are putting an increasingly large burden on people and society. Genes and lifestyle factors are important to leading healthy and long lives.

Dr. Donna J. Nelson shared the key messages from the Engineering and Innovation concurrent sessions. The information discussed can be divided into three categories: product or purpose, process, and people.

Regarding product or purpose, new nanomaterials are needed to extend beyond Moore's Law. Important goals include applications of collaborative, connected, and cognitive robots, and shifting from weak to strong artificial intelligence.

As for process, some important goals are to reinvent the chemical industry, reduce our carbon footprint, achieve additive manufacturing, increase synthesis functionalization and modeling of new materials, automate manufacturing, increase design-led innovation, and improve technologies, systems and customer support. There are also concerns and considerations surrounding autonomous behaviors and supervised behaviors.

Regarding people, goals include fostering more skilled people through augmented reality, and providing better education and working environments to foster creativity and innovation. At the same time there are concerns such as ethical, legal, social, and economic issues relating to innovations in robotics and artificial intelligence.

Nelson, Donna J.

Falk, Jim

The next reporter was Professor Jim Falk, who spoke about the key messages from the Earth Science concurrent sessions. Human impacts on the planet, particularly climate change, are highly concerning. There have

Hassan, Mohamed Hag Ali

Mazur, Eric

been remarkable advances in science and technology, but more still needs to be done, especially with regard to mitigating climate change.

Common themes across the sessions include the need for greater cooperation, as well as engagement across all scales of human societies to address issues. For example, issues relating to water or disaster risk reduction and resilient societies relate to many sectors and stakeholders, and often require local, regional and international cooperation.

Additionally, advances in science and technology, notably in satellite sensors, have enhanced our ability to monitor climate change and produce models for predicting potential disasters. However, different models can produce different results. Much more data and better modelling is needed. Another challenge is to get necessary information in time and in an accessible form to potentially vulnerable communities.

Regarding oceans, one major challenge is visibility. Oceans cover 75% of the Earth but too little is still known about them. A substantially expanded effort for marine monitoring is urgently required. Notably changes to the ocean, and the fish on which so many people depend for their protein, and damage to sensitive features like the Great Barrier Reef, need to be understood and tracked.

In all aspects of Earth systems, the sharing of data and analysis holds great promise for solving our problems, but there are serious barriers to its use by decision makers and communities which must be addressed. Greater efforts should be made to facilitate innovation both in science and technology, and in governance, together in a more integrated way so that decision making can be better informed by the best scientific knowledge.

In all aspects of Earth systems, the sharing of data holds great promise for solving our problems, but issues related to this must be addressed. Moreover, serious efforts should be made to facilitate innovation in science and technology, and also governance.

Dr. Mohamed Hag Ali Hassan then presented the key messages from the Cooperation in S&T concurrent sessions and suggested that the purpose of such cooperation should be achieving the Sustainable Development Goals.

In many cases, collaboration among academia, industry, and government has been very successful. However, in developing countries, this collaboration is still unsatisfactory. In addition, innovations in science and technology, business, and social implementation must be integrated.

Kitano, Hiroaki

Johnson, Ray O.

Governments can play an important role in promoting international collaboration. Furthermore, accelerating developments in ICT offer new opportunities for collaboration.

Subrina, Samia

Platt, Glenn

For such collaboration to succeed, all parties must have clearly defined and agreed upon roles, and results must be equitable to all parties.

The international science and technology landscape is rapidly changing and becoming increasingly multipolar. International assistance is needed for capacity building. Such assistance would be most effective if directed to research universities and centers of excellence. Developing countries must formulate their own national science and technology plans, based on national needs, and with the aim of achieving the SDGs.

Science diplomacy and international collaboration are two sides of the same coin, and contribute to the advancement of science and the generation of innovation. Academies of science also have a role to play in influencing international policymaking. Additionally, it is important to raise awareness among future leaders of the importance of science diplomacy.

Next, Dr. Eric Mazur reported on the key messages from the S&T and Society concurrent sessions. Exponential change is forcing society to adapt in an unprecedented way. For example, the way knowledge is shared has been transformed. Crowdsourced knowledge could increase the pace, quality and transparency of innovation. The lack of ownership might promote open innovation and multi-disciplinarity, but the question is how individual contribution would be rewarded and incentivized.

There is an increasing ubiquity of knowledge and lack of verification of that knowledge. As a result science is treated with growing suspicion. Better communication of the value of science is crucial.

The goals of science and politics can seem to be conflicting. Science is international and long-term, while politics are national and short-term. There is a growing distrust between scientists and politicians and scientists must do more to engage politicians and advocate scientists. Scientists need to be better politicians and politicians need to be better scientists.

Educational needs are changing. Problem-solving is becoming more important than knowledge, and education must instill in students higher-level thinking skills. In addition, university rankings are counter-productive to innovation in education, and universities must find the courage to change and improve the way they educate.

Dr. Hiroaki Kitano then shared the key messages from the ICT concurrent sessions. There were three major issues throughout: the impact of artificial intelligence, issues relating to data, and cybersecurity.

Rapid progress continues to be seen in artificial intelligence. However, there are concerns about how artificial intelligence will affect jobs and society. Society needs to consider how to mitigate its impact.

With regard to big data, companies that can harvest large amounts of data will be at a major advantage. This could create inequities among companies and countries. For example, the United States and China have a dominant position in producing and harvesting data. We must ensure data is presented fairly and without bias, and that it is treated in an ethical manner.

With the emergence of autonomous systems, society needs to learn to trust systems. At the same time, society could put itself at risk by becoming too reliant on autonomous systems. It is also important to harmonize artificial intelligence into society while recognizing the different frameworks within which artificial intelligence and human intelligence operate.

Overall there are light and dark sides to artificial intelligence, but artificial intelligence has the potential to transform our society for the better and offer new solutions to the problems we face.

The final reporter was Dr. Ray O. Johnson who presented the key messages from the Cities and Mobility concurrent sessions. Transportation and housing are vital to human living, and consume a significant amount of our incomes. They are also major contributors to climate change. Furthermore, population growth and urbanization are accelerating.

Society has the opportunity to improve mobility and smart cities, but if we take the wrong decisions or do not act, we could face disaster. To make the right change requires scientists, policymakers, and society to work together. Integrating hard and soft infrastructure is also essential.

In mobility, it is certain that autonomous vehicles will be realized. However, there is a risk that the "lights" of this technology will be overemphasized and the "shadows" underemphasized. Cutting-edge mobility systems are being developed in some countries but less so in others. Rethinking transport means rethinking cities and how we live, which requires public-private partnership.

Another important question is what the role of cities is in a connected world with many virtual spaces. New infrastructure is needed to adopt to this new reality. Smart cities will not be realized on their own and require top-down and system-based approaches.

Reports by Future Leaders

Dr. Samia Subrina believed that STS *forum* has given young leaders the platform to share ideas, network, and meet top leaders from different sectors in a common plaza. In particular, the Nobel Dialogue has been an excellent opportunity. The future leaders also share the common beliefs that independence is indispensable for science, collaboration and effective communication are needed to create societal benefits, and the active participation of future female leaders is essential.

Next, Dr. Glenn Platt described his participation at STS *forum* as an emotional journey. There were lows such as learning that the Royal Academy is no longer certain of benefits of science and technology, and that it may be difficult to meet the goals of the Paris Agreement, but also highs such as the stimulating discussion and the many inspiring opportunities, such as the Nobel Dialogue. Future leaders share the common goal of seeking the betterment of society. They also are confident that they can tell the story of science and technology more effectively, and are certain that science and technology are the key to improving the world and solving major challenges such as poverty and gender equality.

Discussion

The speakers shared their thoughts on mitigating the "shadows" of science and technology. Students and the general public need to learn to appreciate science and scientists. It is important to transfer not only scientific knowledge, but also scientific methodology. We need to improve communication to address misunderstandings about science and incorporate more social scientists. Greater representation of scientists in the political sphere would be beneficial. Artificial intelligence could exacerbate disparities in society and serious discussions about this issue are required.

Energy and Environment
Future Prospects of Oil and Gas

[Chair]

Des Rosiers, Frank, Assistant Deputy Minister, Innovation and Energy Technology, Natural Resources Canada, CANADA

[Speakers]

Haji Darman, Nasir, Head of Group Research and Technology, Petroliam Nasional Berhad (PETRONAS), MALAYSIA

Karpushin, Oleg, Executive Vice-President for Production, Exploration and Oil Field Services, JSC NC "KazMunayGas", KAZAKHSTAN

Ono, Yota, Director-General, Natural Resources and Fuel Department, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, JAPAN

Santo, Masaji, President & CEO, Chiyoda Corporation, JAPAN

Smith, Christopher, Advisory Board Fellow, Baker Institute for Public Policy, Rice University; Managing Partner, Paladin Equity LLC, U.S.A.

Xiansheng, Sun, Secretary General, International Energy Forum (IEF), SAUDI ARABIA

Chair: Des Rosiers, Frank

Opening Remarks

The chair opened the session by reminding the participants that the session's emphasis focused on the oil and gas sector, mentioning the focus and commitments of governments, including addressing issues coming out of the Paris Agreement, the Canadian oil and gas situation, including energy reserves, the importance of the enactment of action plans around carbon, mitigation measures, adaptation, and innovation.

The session speakers were then invited to offer their comments. They discussed that countries and companies need to transform their energy culture, how companies, specifically Petronas, can transform and have

transformed, including simplifying processes, understanding supply and demand, and putting emphasis on gas, and also reducing costs of operations. They also discussed that the oil and gas industry's energy demand is changed by oil production, that high prices of one energy source stimulates exploration of other energy sources, emphasizing the importance of developing energy exploration, the abundance of hydrocarbon deposits, that alternative sources of energy will increase and slow fossil fuel energy but it is unlikely that it will not eliminate the use of fossil fuels, and the need for a holistic change in the way society consumes energy. There was also discussion of what the oil and gas industry will look like in 2050 in Japan, such as the future of the oil refinery business, renewable energies phasing out coal use, the key factor of converting to electric vehicles, how to go through an energy transition period, and the increase of oil prices because of destabilization in the Middle East which could be a catalyst for Japan's utilization of liquefied natural gas.

Discussion was also held on Chiyoda Corporation's new approach to gas-to-power business, including new technology for new energy, such as a floating power vessel that can provide on-shore power that can deliver energy in a shorter time and at a smaller cost which should replace on-shore power facilities, such as power plants, and that large scale and long distance hydrogen storage is possible by using hydrogen technology. Topics also included that climate is a universal challenge faced by many countries and companies, the

private sector provides commitment to improvement as per the Paris Agreement, the future is difficult to see because technology will bring changes that we don't expect, and very large companies with stock prices that rely on the growth of oil will be forced to reconsider their plan in the future; as well as the many challenges surrounding fossil fuels and renewable energies, including how to make the energies clean, and that to help overcome these challenges, the United States needs to be involved in the Paris Agreement because it is a large country with many resources.

Discussion

Following the opening remarks, a discussion was held. The participants discussed how closing coal mining sectors in different countries would affect jobs, challenges around aligning the forecasts of oil and gas, including how much natural gas will be involved in energy consumption and production, how politics impact some of the forecasts, and how to balance research investment between renewable energy and oil and gas. Discussion was also held on how harvesting renewable energy will become cheaper by scaling up the industry, and that scaling up could be achieved by improving storage space for solar and wind power; how long hydrocarbons could sustain the world, the possibility of making renewable energy cheaper, making hydrogen energy cheaper and using fully electric cars in the future; the Paris Agreement, including its poor structure due to its voluntary nature, and the need for the Paris Agreement to be more concrete, the emphasis of carbon capture and storage (CCS); the fact that CCS is too expensive to be adopted without government subsidies, and the importance of price signals related to oil consumption.

Energy and Environment
Nuclear Technology Prospects

[Chair]

Lester, Richard K., Japan Steel Industry Professor and Associate Provost for International Activities, Massachusetts Institute of Technology (MIT), U.S.A.

[Speakers]

Amano, Yukiya, Director General, International Atomic Energy Agency (IAEA), AUSTRIA
Bigot, Bernard, Director-General, ITER Organization, FRANCE
Fujita, Reiko, Program Manager, Impulsing PAradigm Change through disruptive Technology (ImPACT), Japan Science and technology Agency (JST), JAPAN
Hirano, Toshio, President, National Institutes for Quantum and Radiological Science and Technology, JAPAN
Irish, Simon, Chief Executive Officer, Terrestrial Energy Inc., CANADA
Wieland, Patricia, Head, World Nuclear University, U.K.

Opening Remarks

The chair opened the session by emphasizing the importance of science for the topic of nuclear technology prospects because it is related to some of the world's greatest challenges, including global security, public health, climate change, and fundamental laws of nature, such as the structure and origins of the universe. The era of nuclear science and technology is in its early stages, and it is nearly impossible to meet the world's appetite for energy and reduce carbon emissions without using nuclear energy. There is a need for innovation of nuclear power technology to assist in decarbonization. Main challenges for rapid growth of nuclear energy have to do with governments, public education and policies for mitigation, and how the nuclear energy field can attract youthful talent.

Chair: Lester, Richard K.

The session speakers were then invited to offer their comments. They reiterated the fact that nuclear science and technology is still young, and discussed the fact that there is no international standard regarding nuclear technology. One of the most important challenges is to try to develop a common standard on the way nuclear power is developed, and we would receive valuable benefits from international cooperation because not all countries have human resources to address important issues, such as waste management. The low end of the nuclear power forecast for 2050 is that nuclear power will be the same and at the high end there will be an 80% increase. There was discussion on the importance of using nuclear technology in the medical field to achieve unique goals, the fact that safety and security of nuclear power is in the hands of each country, that the International Atomic Energy Agency is appropriate for the issuance of safety standards for nuclear power, such as making action plans for disasters, and that women are very important to involve and recruit in the nuclear science and technology community because now it is dominated by men.

In order to attract more people to the nuclear area, there are courses and classes to discuss progress of nuclear power in different countries. The main barriers found in the energy market involve subsidies and taxes against nuclear energy, and regulation of nuclear energy needs to be worked on because it creates a negative impact on the nuclear energy industry. Public acceptance is important because nuclear power has a negative public image. There

was also discussion on the development of radioactive waste treatment, with focus on the need for innovation because many nuclear systems were developed decades ago, and no new nuclear research has started because fundamental research and development needs to be focused on instead of technical development. For the future of energy, we must focus on the most scalable energy source and an excellent option is nuclear. However, which kind of nuclear energy is the key question. Molten salt has many commercial opportunities because it approaches the fundamental challenges, such as heat dissipation, and it can be used to create a nuclear power plant that can compete with fossil fuels. Finally, there was discussion on the mission to realize nuclear technology applied to the medical field in order to overcome serious health issues, such as cancer, and emphasis on international cooperation and breaking down the explosion of diversity. Quantum scalpel, a next generation heavy ion radiotherapy, was proposed as an example. The importance of international cooperation was emphasized for not only the development of science and technology, but also for sustainability of a peaceful and spiritually rich human society.

Discussion

Following the opening remarks, a discussion was held. The participants discussed standardization in depth, such as the fact that if nuclear energy expects to go forward, we need regulation about what safety means between countries, how new, young talent can be attracted to the nuclear area, how nuclear energy can compete with other forms of energy, and the public perception on safety. There was also discussion on the necessity of safety of reactor designs, and the development of new designs which are intrinsically safe, technical aspects related to alpha therapy as a means of radiation therapy, waste management and decommissioning, public participation and access to information, and recent developments in South Korea that reversed a nuclear policy to phase out nuclear energy within the next 30 years. Finally, there was discussion on nuclear technology applications to the medical field such as radiotherapy, safeguarding nuclear products, increasing international cooperation, the importance of analyzing a future without the use of nuclear power, and the need to work on public acceptance and education with regard to safety measures and issues.

Energy and Environment
Renewable Energy

[Chair]

Sofronis, Petros, Professor, Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, U.S.A.; Director and Professor, International Institute for Carbon-Neutral Energy Research (I2CNER), Kyushu University, JAPAN

[Speakers]

Bonhoff, Klaus, Managing Director (Chair), National Organization Hydrogen and Fuel Cell Technology (NOW), GERMANY

Isaacs, Eric D., Executive Vice President for Research, Innovation and National Laboratories, University of Chicago, U.S.A.

Muraki, Shigeru, Executive Adviser, Tokyo Gas Co., Ltd., JAPAN

Suematsu, Hiroyuki, Director-General, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry (METI), JAPAN

Verwaerde, Daniel, Chairman, Alternative Energies and Atomic Energy Commission (CEA), FRANCE

von Klitzing, Klaus, Director, Department, Low Dimensional Electron Systems, Max Planck Institute for Solid State Research, GERMANY [Nobel Laureate 1985]

Chair: Sofronis, Petros

Opening Remarks

The chair thanked all participants for their attendance of the session on Renewable Energy and encouraged all attendees to share their views openly in order to promote the most robust discussion possible. He then gave opening remarks, emphasizing the importance of development of renewable energy (RE) and highlighting the growing momentum in the development of RE and the potential of RE to be an engine for creation of new jobs. He drew attention to the paradox that exists in the interplay between development and implementation of renewables and the existing fossil-fuel based model for the energy market. He suggested that we need innovative solutions to fully implement RE, such as grid-scale energy storage capacity, the so-called super grid, the smart grid, microgrids, nanogrids, etc.

The session speakers were then invited to offer their comments. They discussed how humans must find a way to adjust to the ever-increasing population with modern science and technology; that affordable and clean energy is the most important basis for the future; that burning our resources continues to increase greenhouse gasses which, in turn, increase the global temperature; that by the end of the century, most energy will be from renewable energy; that in the long run, solar panels may be the best source of renewable energy; that current photovoltaics can compete with fossil fuels; and that photovoltaics and hydrogen are the gold standards for a better future. In addition, an introduction of Japanese government policies in climate change was given, as well as an explanation of the importance of developed countries continuing to develop innovative technology and business to contribute to CO_2 reduction; that renewable energy and natural gas will be major sources of energy in Japan by 2040; the importance of deploying renewable energies through subsidies; and the potential contribution of Japan's business methodologies and technology to reduction of CO_2. Further topics included how to maximize the use of renewable energy; the impracticality of transporting hydrogen using pipelines for long distances; the development of hydrogen energy carriers in order to transport it safely and economically; and the importance of utilizing ammonia for power generation due to its high potential to be a carbon-free energy source. In addition, there were exchanges of ideas on how renewable power, wind, and photovoltaics are predominant sources for the future of energy; the need to focus on renewable energy in transportation because the future of mobility will have to be emissions-free and powered by renewable energy; how meeting CO_2 reduction goals will only be possible using entirely renewable energy powered vehicles; that some markets offer generous subsidies schemes to grow the electric vehicle market; and the need for battery and fuel cell technology to advance in order to electrify vehicles. There was discussion on the importance of overcoming storage barriers, summarized plainly, if we solve the storage problem, we solve the energy problem; the need for research to be more integrated earlier with policies and taxes, not just science and technology; the importance of collaboration on material that is economically feasible; policies around greenhouse gas emissions; and how the social cost of carbon is being addressed. Finally, the necessity for cars in France not to rely on gasoline, but on electricity by 2030; how more than 90 percent of energy that is produced in France is already low carbon; the key issues of investment costs and energy storage capacity; the fact that hydrogen is an excellent choice because of its flexibility; and

how batteries and hydrogen are an integral point in the renewable energy field were all topics that were discussed.

Discussion

Following the opening remarks, a discussion was held. The participants discussed the fact that ether will not solve the energy problem; that photovoltaics research and development depend on government finance in Japan; the importance of hydrogen in an integrated energy system combining power, heat and transportation; how other technologies will continue to lower the cost curve; that hydrogen is not the only answer to renewable energy; the possibility of a zero-carbon integrated energy system, which has as its primary challenge the realization of the optimal system; that if we can triple battery storage capacity, then batteries would beat hydrogen in many applications; the challenge of fossil fuel legacy infrastructure; the understanding of true economics regarding renewable energy; the fact that customer demand is driving renewable energy; that getting storage and an effective grid will ensure that renewable energies are possible; that there is no one solution that is universally ideal considering how many countries and people will use renewable energy; that the local management of energy production with a well-equipped grid is essential; that storage is important for the short-, medium-, and long-term; that the speed of getting the grid set up will determine the speed at which renewable energy vehicles can be available; that the cost of renewable energy has decreased and will continue to decrease; and the economics behind choosing types of technologies for renewable energies.

Energy and Environment
Best Mix of Energy

[Chair]

Korhola, Eija-Riitta, Delegate, Consultative Commission on Industrial Change, The European Economic and Social Committee; Advisor in EU-affairs, Doctor of Environmental Politics, former Member of the European Parliament (1999-2014), FINLAND

[Speakers]

Carty, Arthur J., Inaugural Executive Director, Waterloo Institute for Nanotechnology, Mike & Ophelia Lazaridis Quantum-Nano Centre, University of Waterloo, CANADA

Furukawa, Kazuo, Chairman, New Energy and Industrial Technology Development Organization (NEDO), JAPAN

Kearns, Paul, Interim Director, Argonne National Laboratory, U.S.A.

Kodama, Toshio, President, Japan Atomic Energy Agency (JAEA), JAPAN

Ryan, Eamon, Leader, Irish Green Party, IRELAND

Opening Remarks

The chair opened the session by mentioning the fact that energy must be addressed to help climate change, energy is fundamentally important but there is much misunderstanding and many fallacies, the optimum mix of energy depends on a time frame, there is no silver bullet which would solve the world's problems in a timely manner, and that at present we have no sustainable global energy source, Germany has made the largest investment in solar and wind but has not reduced emissions since 2009. Because societies have always replaced one source of energy with another, it is important to look at the short-term reality, mid-term planning, and long-term reasoning, and Finland's energy situation cannot abandon nuclear energy and has no energy reserves.

Chair: Korhola, Eija-Riitta

Following the opening remarks, a discussion was held. The participants discussed the fact that in order to prevent global warming, energy security, economic efficiency, environment and safety must be considered in a balanced manner, there has been strong opposition to nuclear power in Japan since the Great East Japan Earthquake, the risks related to nuclear energy utilization must be controlled, now energy can be used abundantly in Japan based on previous efforts, mankind must control and manage nuclear energy because nuclear energy is important to reduce emissions; electrification of transportation is creating a new demand for electricity, interest in hybrid electric aircraft is increasing, digitization is driving energy consumption in the world, energy storage is becoming more affordable and will allow the best mix of energy to be optimal, cheap solar and batteries are essential for the future, and international cooperation between governments is vital for the grid of the future; the future will be 100% renewable, renewable energy is decreasing in cost, renewable energy could never be held for ransom because it is everywhere unlike oil, efficiency and renewable energy have to be in balance, we have to decide what happens in 2040 in the next two or three years, and the renewable revolution is happening and California and Germany are examples that it is happening; energy security is the most important issue and the environment is the second most important issue, nuclear power is a fundamental power in Japan, we must keep to the Paris Agreement because in 2050 we must reduce half of Earth's greenhouse gasses and every country must try in order to realize such a target; within four decades global energy demand is expected to double, the population is growing

fast and it will be challenging to supply global energy to make everyone comfortable in the world, practical achievement of the best mix of energy will depend on resource availability, accessibility and cost, Canada's energy mix situation, specifically Ontario's energy mix, the role of Canada's government in energy mix, and carbon capture and storage in Canada.

Discussion

Following the opening remarks, a discussion was held. The participants discussed the best energy mix for the future, the fact that government policy would determine the best mix of energy, geographical factors also play a role in the best energy mix, and reliability and affordability is the most important for the best energy mix; the best mix of energy is aimed at reducing CO_2, the choice of the mix of energy is influenced by politics, cost, sustainability and other circumstances; the best mix of energy clearly depends on where you come from in the world; a safer nuclear technology that is based on thorium not uranium, global power from nuclear energy, the electricity problem in Africa and the Philippines, and energy storage are the most important issues now; some countries are already 100% renewable, transforming countries in the Middle East into renewable-energy-using countries should be a goal, we should save energy resources for the future, the importance of technology neutral policies, and investments and consumers drive influence on the best mix of energy.

Life Sciences
Environment and Health

[Chair]
Nagai, Ryozo, President, Jichi Medical University, JAPAN

[Speakers]
Fernando, Sirimali, Chairperson, National Science Foundation of Sri Lanka, SRI LANKA
Gilchrist, Moira, Vice President Corporate Affairs Reduced-Risk Products, Philip Morris International Management SA, SWITZERLAND
Murad, Ferid, Senior Research Advisor, Palo Alto Hospital, U.S.A. [Nobel Laureate 1998]
Soebandrio, Amin, Chairman, Eijkman Institute for Molecular Biology, INDONESIA

Opening Remarks

The chair welcomed the participants and opened the session by first speaking about homeostasis and the relationship between people's natural and social environments and their health. He also touched upon the development of individualized medicine; as well as the impact of human activities on the environment, such as pollution, the spread of zoonotic diseases, and the rise of hospital-based infections. In addition, the chair discussed the importance of collaboration and the sharing of health-related data, noting also the challenges related to the sharing of such information, such as privacy concerns.

Chair: Nagai, Ryozo

The session speakers were then invited to offer comments. They mentioned the interconnectedness of different ecosystems within our dynamic environment, and the mutual influence that the environment and humans have on each other's wellbeing; the continued growth of the human population and the accelerating damage humans have caused to the environment in their pursuit of development and prosperity; the need for deeper understanding of microbiota,

which could yield greater insight into health and diseases; the importance of sustainably managing resources such as livestock, marine bio-resources, and forests, the demand for which continues to grow due to economic development; emerging infectious diseases in developing countries, especially zoonotic diseases, such as avian flu, Zika, or Ebola, and the accelerated spread of infectious diseases due to the increasingly globalized activities of humans; the way that social, economic, and cultural factors can affect the environment and human health; advances in technologies for tackling mosquito-borne diseases; the value of combining clinical and basic science educations and research; research relating to cell signaling with cyclic AMP, cyclic GMP and nitric oxide, and the insights such research has yielded in understanding human health and addressing various diseases; and alternative strategies aimed at reducing the harm of consuming tobacco by smokers who do not intend to quit smoking, including electronic cigarettes and systems that heat rather than combust tobacco, to complement existing strategies to prevent people from becoming smokers and encouraging smokers to stop smoking.

Discussion

A group discussion was then held. The participants covered matters such as intellectual property issues related to medical research and drug discovery; the need to further improve research collaboration between academia and industry, for example through the provision

of grants for that purpose; the value and challenges of sharing health and research data; the need to develop technological and other solutions to reduce indoor pollution; research on microbial-human relationships that is valuable for better understanding of well-being and disease; research on the microbiomes of other organisms and its application in agriculture; ways to develop healthy diets and habits, and how this can be influenced by cultural practices; the importance of tackling noise and light pollution, and the biological impact such pollution can have; the provision of tobacco products with lower health risks than cigarettes and the importance of accurately communicating the nature of the products to consumers; how rapidly establishing networks of experts to respond to emerging or re-emerging diseases, such as Zika, can not only tackle the outbreak but also build up experience and knowledge for the future; the importance of engaging the population to make sure that they follow health-related advice and take the necessary actions; the value of clinicians who are also researchers, and the difficulties of balancing clinical practice and research responsibilities; the use of big data in diagnosing and treating diseases; and the potential for stem cell research to pave the way for gene therapy and the challenges that still need to be overcome before this can be achieved.

Life Sciences
Genome Engineering

[Chair]
Liu, Edison T., President and CEO, The Jackson Laboratory, U.S.A.

[Speakers]
Falk, Anna, Associate Professor, Department of Neuroscience, Karolinska Institutet, SWEDEN [Future Leader 2016]
Hamburg, Margaret A., Foreign Secretary, National Academy of Medicine; former Commissioner, U.S. Food and Drug Administration (FDA), U.S.A.
Leyser, Ottoline, Director, Sainsbury Laboratory, University of Cambridge, U.K.
Smedley, Mark, President, Genetic Sciences Division, Life Sciences Solutions, Thermo Fisher Scientific, U.S.A.
Suzuki, Rami, Senior Director, Head of Business Development, Janssen Pharmaceutical K.K., JAPAN

Opening Remarks

The chair opened the session and discussed the significance of gene engineering and editing and developments in the field. He first explained that the CRISPR/Cas technologies have advanced gene engineering and editing and brought the field to the fore. The chair also reminded the participants of the importance of distinguishing between somatic genetics and germ-line genetics in discussions on this subject, as well as imminent developments and hypothetical developments. Furthermore, intentional and unintentional risks are an important topic to consider.

Chair: Liu, Edison T.

Next, the session speakers gave comments. They first discussed the benefits and risks of gene engineering and editing, such as the ability to create disease models for developing potential treatments or carrying out cell

transplantation treatments; difficulties surrounding germ-line engineering, such as developing the necessary regulation; unknown consequences that can occur from correcting gene mutations; and the gap in the understanding and interest between scientists and civil society, and the need to communicate more actively with the public. They also touched upon subjects such as the application of genome editing technologies to optimize agricultural systems; and fostering more constructive discussion on genetic engineering and related legislation. In addition, they spoke about the importance of medical tools manufacturers not only providing healthy, clean and safe technologies, but also working with users to ensure that these tools are applied appropriately; and the importance of industries and regulators holding regular discussions regarding emerging technologies. Furthermore, the speakers mentioned how the systematic application of the stem cell and iPS technologies can lead the way to deeper understanding of the technologies, and the developmeant of new treatments and medicines; the need to make medical technologies and treatments available to a wider section of the global population, such as by decreasing the cost of genome editing; and the value of collaboration not only in research and the sharing of data, but also areas such as public engagement and regulatory discussion. Finally the speakers touched upon the complexity of regulating gene engineering and editing technologies, which has not only scientific but also legal and ethical implications, and ongoing dialogue in this area; as well as the dangers posed by the misapplication of such technologies, such as bio-weapons and bio-terrorism, and ways to tackle them.

Discussion

A group discussion was then held. The participants covered subjects that included why and how genome engineering and editing technologies are being applied; the responsibilities of society in relation to these technologies, including ethical and moral considerations; ways to generate dialogue and reach out to the public, and the influence of the media and politicians in fostering understanding; the use of such technologies for bio-processing; challenges around scaling up and scaling out genome engineering and editing technologies; the importance of regulatory discussions and the need to tackle regulatory disconnects; potential unexpected consequences; ways to generate actual human benefit from genome engineering and editing technologies; the idea of being able to engineer biology and the questions and consequences this raises; the question of whether genome engineering and editing technologies are a necessity or a luxury; the many opportunities that these technologies offer, such as synthetic bio-banking or the pooling of the data of bio-pharma companies; questions relating to intellectual property around CRISPR; GM technologies

and their application in plants; the importance of clear labelling of GM products that can be understood by the public; trade-based regulation; the regulatory challenge of handling the different technologies that will be coming online at different times; developing established practices and norms through international dialogue; the importance of involving as broad a spectrum of society as possible in determining where to draw the line between what is safe and good and unsafe and bad; the question of whom such technologies benefit and, consequently, who should decide how it is used; and the question of which diseases should be targeted when using these technologies.

Life Sciences
Advanced Medicine

[Chair]

Collins, Mary, Dean of Research, Okinawa Institute of Science and Technology Graduate University (OIST), JAPAN

[Speakers]

Baltimore, David, President Emeritus, Robert A. Millikan Professor of Biology, Division of Biology and Biological Engineering, California Institute of Technology, U.S.A. [Nobel Laureate 1975]

Diarra, Amadou, Head, Global Policy, Advocacy & Government Affairs, Bristol-Myers Squibb Company, U.S.A.

Ogiwara, Shinsuke, Assistant General Manager, EM Business Unit, Business Planning, JEOL Ltd., JAPAN

Takahashi, Jun, Professor, Department of Clinical Application, Center for iPS Cell Research and Application, Kyoto University, JAPAN

Zerhouni, Elias Adam, President, Global Research & Development, Sanofi SA, FRANCE; former Director, National Institutes of Health (NIH), U.S.A.

Chair: Collins, Mary

Opening Remarks

The chair began by explaining that the theme of the session, advanced medicine, tied into and built on the discussion of the previous session in the life sciences track, which was on the subject gene editing and engineering.

The session speakers then offered their comments. They spoke about low molecular weight drugs and their advantages, such as their relative inexpensiveness, and their ease of intake and synthesis; tools for drug discovery and development, such as electron microscopes, NMR spectrometers, mass spectrometers, as well as emerging developments in cryo-electron microscopes; developments in gene therapy research, such as t-cell research, the insertion of genes into stem cells to treat sickle cell disease, the use of genes to provide antibodies, and selective insertion of genes into dendritic cells; advances in research on methods to target microRNAs, which play a key role in immune regulation, in disease settings; the many contributions iPS cell technology can make to human health care, including regenerative medicine, facilitating drug discovery and making it more efficient, and transforming the way we understand biology; the need to recognize the heterogeneity of the human population in disease treatment; the importance of detailed characterization of diseases, including identification of the biomarkers and pathways; the need to further study human biology in a deeper way, based on novel basic discoveries and their application in the human population; the value of wiser health care and regulatory policies for the effective implementation of health care technologies; the need to optimize the prioritization of which diseases to target for research and treatment implementation so as to ensure the maximum public health impact; the fact that it is possible to make advanced medicines accessible in developing countries, when multiple stakeholders cooperate, although it is still difficult; challenges in securing accessibility to advanced medicine in developing countries, including the problem of husbands making decisions about whether or not their wives receive a certain treatment, stigma surrounding treatments and the need to communicate and convince the public, and the importance to work with many partners; and how oncology and cancer treatment is the next frontier in Africa.

Discussion

Following this, a group discussion was held. The participants touched on cultural and practical challenges to providing medical treatments in developing countries; the fairness of drug pricing in developing countries; providing incentives for drug development to companies; how stratification in drug development can lower risk; the emergence of gene therapy as a viable treatment method; the role of epigenetics; the usefulness of micro- and nano-scale devices for studying molecular interactions; barriers for scaling gene therapy, including the issue of diagnostics sometimes being more expensive than treatment; the role that can be played by non-profit organizations; the importance of combining stem cell therapy with other forms of therapy for the maximum effect; determining which diseases it would be most appropriate to treat with stem cell therapy; the importance of educating society about unproven stem cell therapies; the necessity of harmonizing regulations worldwide; the need to discuss issues surrounding end-of-life, amidst ever advancing treatment capabilities and ever greater longevity; risk related to new technologies and how they are perceived by investors and governments; the need for more precise and rapid diagnosis; the role of open-mindedness and interdisciplinary knowledge in generating innovation; the importance of engaging different stakeholders to make advanced treatments accessible to a wider section of the population; the need for developing countries to prioritize their efforts based on societal need; and the importance of community involvement and engagement when testing new treatments.

Life Sciences
Healthy Aging

[Chair]

Welham, Melanie, Chief Executive, Biotechnology and Biological Sciences Research Council (BBSRC), U.K.

[Speakers]

Agre, Peter, Director, Johns Hopkins Malaria Research Institute (JHMRI), Johns Hopkins Bloomberg School of Public Health, U.S.A. [Nobel Laureate 2003]

Hunt, Tim, Visiting Researcher, Okinawa Institute of Science and Technology Graduate University (OIST), JAPAN; Emeritus Group Leader, The Francis Crick Institute, U.K. [Nobel Laureate 2001]

Imura, Hiroo, Professor Emeritus, Kyoto University, JAPAN

Zhou, Lihan, Chief Technology Officer, Management, MiRXES Pte. Ltd., SINGAPORE [Future Leader 2016]

Opening Remarks

The chair opened the meeting and stated as life expectancy increases around the world, managing aging populations socially and economically is a challenge being faced by developed and developing nations worldwide. How can science and technology facilitate healthy aging? Gaining a better understanding of aging can help develop better treatments and even preemptive treatment or better prediction of disease incidence. It will also be important to better understand the lifestyle factors that affect healthy aging. There are also opportunities, for example, for robotics and digital technologies to facilitate the independent living of senior citizens, and lifestyle apps to enable people to make the right decisions to age healthily.

Chair: Welham, Melanie

The session speakers then offered comments. They covered topics that included advances in our understanding of aging, including which

organisms age and which do not, as well our body's repair mechanism and the potential that optimizing this mechanism would yield; preemptive approaches for addressing age-associated diseases such as neurodegenerative diseases, cardiovascular diseases, or cancers, which are placing an increasing health and economic burden on societies; how progress in genomic research has made it possible to identify markers for disease, detect the early onset of disease, and screen for potentially at-risk populations; the importance of working with governments and citizens to introduce advanced medical technologies to society and to ensure they are accepted and effectively implemented; how the rankings of the average lifespan in each country show that life expectancy is dependent on more factors than wealth alone; and the personal and societal factors that affect healthy aging, such as the adverse impact of pollution and poor public safety, and the importance of exercise and lifelong intellectual stimulation.

Discussion

The participants then engaged in a group discussion. They spoke about maintaining the quality of people's lives as they age and the question of what exactly "quality" means; the consequences that a society would face, were it unable to support its aging population; how the elderly do not necessarily just receive care, but that they can also provide care to others,

including those younger than themselves; the distinction between a person's life span and their health span, and how society would be better served focusing on the latter; the fact that aging is a multifactorial problem that requires multifactorial solutions, based on the two pillars of socialization and energy, which is comprised of exercise and diet; the value of interventions not only to correct lifestyles but also to ensure people adhere to those new lifestyles, and the role that "coaches" could play in this regard; opportunities for identifying new biomarkers for health; misalignment of incentives in health systems and the issue of reimbursing health care payments; educating next-generation health care providers, as well as broader society; ensuring social readiness and social capital for facilitating healthy aging; government initiatives to encourage diagnostics without disease; the importance of providing lifestyle-related education and incentives for adopting healthy lifestyle practices at different life stages; the role that big data can play in advancing research in areas such as identifying biomarkers or providing better health care support; and the fact that "aging" is still too complicated to define scientifically, with many important questions still needing to be answered.

Engineering and Innovation
Industrial Innovation

[Chair]
Candel, Sébastien, President, Academy of Sciences of France, FRANCE

[Speakers]
Godrej, Nadir B., Chairman, Godrej Agrovet Ltd; Managing Director, Godrej Industries Limited, INDIA
Metivier, Pascal, Senior Executive Vice President, Science & Technology Director, Solvay S.A., BELGIUM
Muromachi, Masashi, Executive Adviser, Toshiba Corporation, JAPAN
Sandvik, Pia, CEO, Research Institutes of Sweden (RISE), SWEDEN
Sankai, Yoshiyuki, Professor, Center for Cybernics Research, University of Tsukuba; Program Manager, JST/Cabinet Office of Japan; Founder/CEO, CYBERDYNE, JAPAN

Opening Remarks

The chair opened the session noting that there are many new fields that can become core technologies for future innovations. There are also issues that would be worth examining such as (1) What methods, environments, processes can be used to foster industrial innovation? (2) One of the duties of academia is to train engineers and scientists. What should be done in terms of training to promote innovation? (3) In the past many revolutionary innovations originated in the advancements of science. Are such revolutions still possible and to what extent future industrial innovations will rely on advancements in basic science?

Chair: Candel, Sébastien

The session speakers were then invited to offer comments. They discussed the importance of reducing environmental footprint by setting future targets on CO_2 intensity, the challenges for reduction of capital intensity of large chemical plants, and co-innovation with downstream industry such as through the development of new materials that support process innovation; innovation is the key to solving constraints on global resources; technology can be used to create green feedstocks as a solution to environmental and energy issues; the sharing economy can spur innovation in efficient transport and mobility systems; innovation can also improve water treatments and provide solutions for agricultural productivity including revolutionary sources for protein without relying on soya; big data analysis and deep learning techniques can be used in manufacturing plants to identify causes of production defects such as failures of silicon wafers used in semiconductors in which the average time required to identify the causes of failure was reduced from six hours to two hours; smart factories that operate based on judgements made by AI to optimize yields will also become a reality using monitoring data from production equipment; open shared test and demonstration facilities can be used to respond to faster product development and time to market, using verification facilities where multiple stakeholders from industry and academia can collaborate on areas of research which are market-pull oriented, providing industrial equipment with qualified operators, technicians, and project managers, thereby reducing development and investment costs by sharing risks; robotics, AI and IoH/IoT (IoH:Internet of Humans) are of great importance for solving the human/social issues of a rapidly aging society; “Cybernics: fusion of human, robots and information systems” can become core technology to solve such issues, bridging robotics, neuroscience, physiology, ethics, and laws.

Discussion

Following the opening remarks, a group discussion was held. It was noted that industrial innovations are needed to respond to many current and future challenges. The role of science was considered next. It was indicated that a lot could be done by making use of existing knowledge but that science had an important role to play as a driver of innovation with longer-term perspectives; science is also essential in solving problems arising in the implementation of new processes, for example in novel manufacturing processes like additive technologies and 3D printing or in atomic processing for electronic devices. It was considered that a good balance had to be reached between curiosity-driven science and applied science. Novel manufacturing processes may appear at first sight more energy intensive and more costly, but one has to examine the overall value chain in assessing these innovations to measure the real benefits provided by these new methods. Education was considered next. Innovation requires specific training methods that should rely on “hands

on experience" and project activities to develop team work, and integrative capacities possibly under joint supervision by industry and academics. It is considered important to promote creativity through training through research and "by doing and not by being taught". Innovation also will have an impact in terms of manpower and skills required. Consideration needs to be given to the displacement of human manpower by automation, robotics and AI and this asks for a clear vision in the management of human resources and efforts to train and develop new skills in the workforce. As an example, the trend in the chemical industry has been toward elimination of control rooms in large plants where they are being replaced by mobile tablets. This requires the use of new methodologies to retrain the workforce, for example by employing virtual reality environments. Collaboration and open innovation can have considerable value. There are outstanding problems facing society that can be solved by embracing collaboration. The sharing economy can help to promote solving new problems. As an example, the collaboration, a consortium of four large automotive manufacturers working together on electric car and autonomous vehicle technology and using a common testbed, has brought a valuable reduction in individual investment costs. There is value in knowledge sharing between industry and academia to advance innovation and financing for innovation and research may be required to supplement market-driven development. One fundamental issue is that of orienting industrial innovation to tackle issues that are most useful to humankind. Participants then discussed the historical progression from Society 1.0, 2.0, 3.0, 4.0 to the recently introduced Society 5.0 that would conceptually mean enhanced connectivity between humans and machines and fundamental issues that may arise from the "Internet of Humans" that is advocated in this framework.

Engineering and Innovation
Future Nanomaterials

[Chair]

Mason, Thomas, Senior Vice-President, Laboratory Operations, Battelle, U.S.A.

[Speakers]

Chinsirikul, Wannee, Executive Director, National Nanotechnology Center (NANOTEC), NSTDA, THAILAND

Fleming, Graham, Professor of Chemistry, University of California, Berkeley; Senior Faculty Scientist, Kavli Energy NanoScience Institute, Lawrence Berkeley National Laboratory, U.S.A.

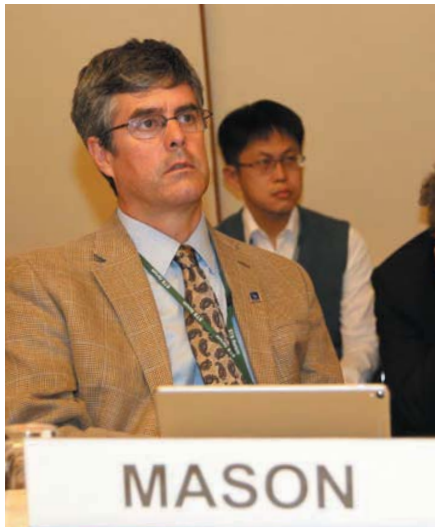
Hashimoto, Kazuhito, President, National Institute for Materials Science (NIMS), JAPAN

Ohno, Hideo, Director and Professor, Research Institute of Electrical Communication, Tohoku University, JAPAN

Sun, Jack, VP and CTO, Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC), TAIWAN

Opening Remarks

The chair opened the session noting that while it is often reported that the idea of nanomaterials began with a talk by Richard Feynman in 1959, it was not cited in literature until the 1980s when the discovery of scanning tunneling microscopy caused a realization that this might actually be possible. What then made it a field of research was the recognition that the extrapolation of Moore's Law would present new challenges at the nanoscale leading to the policy framework being put in place to enable research into nanomaterials to begin. It is now getting more difficult and more expensive to create new facilities for new features sizes as the associated capital costs rise. Meanwhile the tools developed for nanoscience and technology are finding applications in other important areas such as biology.



Chair: Mason, Thomas

The session speakers were then invited to offer comments. The discussions were wide ranging, including that semiconductors are the foundation of every new technology and nanomaterials are critical to continue to advance these technologies; while silicon wafers are still the basis of semiconductors, there are a lot of other materials used in conjunction with silicon to achieve significant advances; there is a lot of research into selective deposition and surface functionalization to create new materials; when building layer-by-layer to create systems, the material must be compatible with lower temperature processes to be able to fit together, and therefore material advances can help to continue to extend the silicon-based nano-electronic industry further for a better and smarter world; where is the greatest need for new nanomaterials in society? ; how can we do a proof of concept for the role of new materials in society? ; what role do public institutions such as universities play in bringing those innovations to society? ; there is a huge gap between developing and showing a new nanomaterial to work and actually developing a final working integrated system based on that material; the Japanese Government initiative “Society 5.0” aims at a “Super-Smart Society” by integrating cyber-technologies such as AI and big data, and physical technologies, such as nanotechnology, sensor technologies and robotics, to bring evolution to many areas including healthcare, manufacturing, traffic infrastructure, finance, etc.. Development of new nanomaterials and processes is critical to realize Society 5.0, such as materials that incorporate mechanisms of living things, materials that directly connect physical space and cyber space, and processes for the fine control of material composition; nanomaterials have attracted major interest and investment and we are now at a stage to make nanomaterials useful for society, requiring refocusing of the discussion on how to implement them in society; when we work in science and technology we

cannot ignore its impact on humanity and sustainability; collaboration is key in the area of nanomaterial development; an industry-driven approach to technology development is still feasible for nanomaterials research; the example of using a new biomarker for reliable diagnosis of diabetes in cases where traditional hemoglobin-based diagnosis cannot be used reliably was provided as a case of application-driven basic R&D; collaboration in nanomaterials and nanotechnologies can play a major role in improving people’s daily lives, and nanotechnology innovation and safety aspects such as risks assessments and public awareness are two sides of the same coin; in the 1960s the semiconductor industry brought together two fields that seemed quite distinct – electronics and information – and now we are seeing the same with the boundary between synthetic nano-machines and biological nano-machines beginning to dissolve; programmable molecular robots may have great significance in the future; nanomaterials could be used for solar power conversion by mimicking photosynthesis, which is the only existing process we know that achieves 100-terawatt-scale power conversion with resilience and scalability; nanomaterials also have the potential to take us into the post-antibiotics era, and have an important role to play in medical diagnosis such as in magnetic resonance imaging.

Discussion

Following the opening remarks, a group discussion was held. The participants covered questions regarding designing interfaces between materials, top-down design of materials features, and precursor materials, all of which can lead to the development of high density systems, noting that this is a great time for universities working in materials and industry-academia collaboration; quantum computing is not yet likely to replace conventional computing until new materials are developed; new functionalities can be achieved by layering combinations of materials that create effects that are not found in nature; public acceptance of nanomaterials is a challenge stemming from fears due to a lack of public awareness; the definition of the word nano may need to be changed due to materials with nanoscale grain size and structural properties sometimes being referred to as nanomaterials or nanotechnology; cost-benefit issues can cause companies to abandon research into nanomaterials; governments may need to provide support for the safety assessment side of nanomaterials development; despite promising expectations for nanomaterials, questions still remain about why it is so hard to realize new applications, and collaboration is required across many fields to achieve the development of new systems; young investigators starting out in nanomaterials need to understand the balance between the detail of their research and impact of what they are working on.

Engineering and Innovation
New Manufacturing Technologies

[Chair]

Engel-Cox, Jill, Director, Clean Energy Manufacturing Analysis Center (CEMAC), National Renewable Energy Laboratory, U.S.A.

[Speakers]

Agrawal, Shailendra, Chief Executive - Operations and R& D and Chief Transformation Officer, Escorts Limited, INDIA

Chetanachan, Wilaiporn, Director, Corporate Technology Office, The Siam Cement PLC, THAILAND

List, Helmut O., Chairman and Chief Executive Officer, AVL List GmbH, AUSTRIA

Murata, Daisuke, President & C.E.O., Murata Machinery, Ltd., JAPAN

Pennington, Miles, Professor, Design Led Innovation, Institute of Industrial Science, The University of Tokyo, JAPAN

Opening Remarks

The chair opened the session commenting that the process of incorporating new technologies into manufacturing is nothing new, but that over perhaps the last 50 years this process has made manufacturing more productive, cleaner and safer for workers, which is tremendously important progress.

Chair: Engel-Cox, Jill

The session speakers were then invited to offer comments. They discussed previous evolutionary steps in manufacturing were mostly related to automation, safety and productivity gains, but Industry 4.0 is disruptive digital transformation, and this is becoming central to any business; superior customer experience and a frugal way of working are going to be the two important aspects for manufacturing businesses in the future, fine tuning input costs and also outputs in parallel through integration of the entire production process; farmers in developing countries tend to avoid investment because they do not see quick return on investment, but platforms can be created to provide innovative services with the investment burden carried by the service provider; identification and prioritization of potential customers can also be improved through digital tools; the spare parts business will also be optimized; frugality and speed are going to be keys to future success; new manufacturing technologies plays an important role in innovation for the next generation of products and services, including optimizing throughout the supply chain, reducing waste, and further reducing costs; smart manufacturing using IoT allows for quick and precise logistics planning, inspection of pipes with robots reduces costs while increasing human safety, while sustainable manufacturing focusing on conserving energy and natural resources; big data and deep learning can be used to understand the relation between product tolerances and customer satisfaction or regulatory requirements, bringing benefits in costs and efficiency; more efficient and rapid servicing can be conducted with augmented reality, using highly trained general engineers combined with specialized engineers at headquarters; in the IoT session it was stated that information is now defined as a gas, while manufacturing has been seen as more solid; however rapid evolution in processes including CAD has changed the nature of manufacturing, and now manufacturers are divided into mass production manufacturers and specialist integrators; for specialist integrators collaboration with customers for product customization is essential; safety and security have become more important differentiators, and providing opt-out for remote monitoring is important for many customers; the role of academia is to give glimpses of the future, such as the potential of Industry 5.0 or 6.0; new technology should not be used to make old products, additive technologies allow for highly functional customized products; combining manufacturing and assembly allows rethinking how a product is made; instant manufacturing is being investigated, inspired by the effects of lightning on a beach, to create products from high voltage discharge; mixing bacteria and mud to manufacture objects could provide an alternative to typical energy-intensive manufacturing processes; robots could become craftsmen, changing the relationship with robots to one of apprentice rather than slave; the future manufacturing is also about the future of society so we must consider the effects of future manufacturing before it arrives.

The chair asked the participants to consider three questions in their discussions: what new technologies are coming in five years, 20 years or 30 years, and how they may affect workers, business processes, customer interactions, the environment and society as a whole.

Discussion

During the group discussions the participants touched upon destruction of the classical economy model through displacement of workers, requiring new methods and tools for quick and continuous learning; limiting factors for growth; how freedom from manufacturing work may result in a return to agriculture with society coming full circle; for development and launch of new products and implementation of new manufacturing technologies, need a long-term approach from an environmental perspective but a short-term approach from a security perspective; new products must be designed with security in mind, but SMEs and startups in particular have difficulties to achieve this, leading to larger companies refusing to work with them due to the risks, and this could stifle innovation; while there are fears about job losses through manufacturing innovation, creating higher value has always been important for humankind, and once again humanity will overcome this challenge opening up new eras for jobs, and therefore retraining and updating of curricula is necessary to reflect the changes in manufacturing; if the workers had been able to vote on the industrial revolution it may never have happened, so which would be worse losing manufacturing jobs due to adopting advanced manufacturing technologies or to lose manufacturing jobs due to failing to adopt advanced manufacturing technologies? – adopting advanced manufacturing technologies at least allows for retraining and also creates a new era of customized products, with associated jobs through consumption and economic stimulus, and wider ranging effects in society.

Engineering and Innovation
Robotics and Autonomous Systems

[Chair]

Dario, Paolo, Professor of Biomedical Robotics, Director of The Bio Robotics Institute, School of Advanced Studies - Pisa, ITALY

[Speakers]

Chen, Wen chi, Chairman & President, VIA Technologies, Inc., TAIWAN

Husain, Bazmi Rizwan, Chief Technology Officer, Group Technology Management, ABB Switzerland Ltd, SWITZERLAND

Kheddar, Abderrahmane, Director, CNRS-AIST JRL (Joint Robotics Laboratory), UMI3218/RL, JAPAN; Titular Full Member, National Academy of Technologies of France (NATF), FRANCE

Maruyama, Hiroshi, Chief Strategy Officer, Preferred Networks, Inc., JAPAN

Ogawa, Masahiro, Corporate Vice President, General Manager Robotics Division, YASKAWA Electric Corporation, JAPAN

Opening Remarks

The chair opened the session with some background on the field of robotics touching on its growth, job generation, forecasts that personal robotics could become an industry the size of the car industry, disruptive new innovations including MEMS, soft materials, and morphological computation, the shift toward robots able to collaborate with humans which will cause a revolution in society, and concerns over sustainability, ethical, legal and social issues.

Chair: Dario, Paolo

The session speakers were then invited to offer comments. They discussed how robotics is all about augmenting human capabilities, and how its development is likely to develop along a similar path to computing, expanding from industry usage to personal usage; it is however not possible to give a vision for the future of robotics, just as it was not possible

to foresee the future of computing; sophistication of robotics is completely tied to ICT developments, and therefore can be considered as a branch of ICT; robotics can be visible or hidden, for example a smart house can be seen as automation of the house or as a robot operating everything in the house, and likewise for autonomous vehicles, they are simply a combination of sensors and actuators; mastering robotics is becoming essential for the competitiveness of countries, even for developing countries; AI is an effort to understand human intelligence, and while early on the field focused on logic, it gradually became clear that cognitive tasks that are easy for humans were much more difficult for computers, however, machines have also become better than humans at these intuitive tasks; for optimization problems the challenge is to provide the right goal in real world tasks, which turns out to be a very difficult task; if an AI-based system is instructed to maximize safety above all else, it will cease to operate as that is the safest course of action; we need to properly understand the technology to work to maximize the value to society; the latest generation of processors have special circuits for AI, for example for training; in many applications improving speed of recognition is very important so semiconductors will continue to play a major role in making these technologies more affordable and widely available; neural engine technology has advanced a lot in the past five years and we are still trying to understand why it works so well; many tools such as VR have been around for a long time, but have finally become mainstream due to a combination of factors including advances in processing power; robots are very much in the news recently, but robots have been used in industry for a long, long time, contributing substantially to economic growth; 80% of

industrial robots are concentrated in five countries – Japan, China, South Korea, Germany and the US; traditionally robots have been given dull, delicate, dirty, and dangerous tasks, due to safety concerns and the difficulties of training them – this is now changing with more sensors and intelligence, using deep learning techniques for training; currently productivity of robots is static over its lifetime, but with intelligence they will have the capacity to improve over their lifetime and to share information, effectively training other robots; robot technology development is closely tied to the automotive industry, and still 60-70% of robot business is driven by the automotive industry; although robots are replacing humans in mass-production industrial processes, they are still not suited to very flexible and variable tasks, which are still mostly done by humans; need to set milestones for deployment of robot automation in the field; will need collaboration among various advanced technologies to create a solution for robot automation in the field.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon; the challenges of combining robotics and AI given the large numbers of constraints and environmental changes; the need to consider more generalized methodologies in order to be able to account for safety; the potential of using an open source model for research, and associated issues with safety, reliability, and competition; regulations could address safety and reliability aspects, but could make the use of an open source model difficult; the example of tea plantations and vineyards was provided as areas of tough terrain where robots are not yet able to perform reliably; for developing economies that export a lot of labor there may be concerns about job displacement, but nursing is unlikely to be affected as the human touch is important; deterministic vs non-deterministic systems; how to make systems failsafe; the challenges of making robots faster, stronger, yet safe to humans; currently machines cannot make the final decision; the need to focus on customer-centric solutions; the potential for sensors on deployed robots to detect how tasks are changing to enhance future robot development; the potential application of robots in inventory management, replenishing parts; how can AI be similar to the human brain; different types of medical robots required for those with cognitive problems and for physical care; the role of robots in everyday life both in communications and task support.

Earth Science
Earth and Space

[Chair]
Squyres, Steven W., James A. Weeks Professor of Physical Sciences, Cornell University, U.S.A.

[Speakers]
Allen, Gale, Chief Scientist (Acting), National Aeronautics and Space Administration (NASA), U.S.A.
Israël, Stéphane, CEO, Arianespace, FRANCE
Okumura, Naoki, President, Japan Aerospace Exploration Agency (JAXA), JAPAN
Takayabu, Yukari, Professor, Atmosphere and Ocean Research Institute, The University of Tokyo, JAPAN
Volpi, Angelo, Science Officer, Bruxelles Liaison Unit, Office for European and International Relations, CNR- National Research Council of Italy, ITALY

Opening Remarks

The chair opened the session by noting that while space can be beneficial, it is not inexpensive, and therefore, it needs to be ensured that space activities are for the benefit of humanity. Although some benefits are intangible, many can and should be tangible.. Space resources can be used to: monitor climate change; monitor space weather; and monitor, mitigate and predict natural disasters and human-made disasters. Nations must work together to achieve these enormous benefits for humanity, while addressing practical issues including the increased potential for collisions and space debris due to the launch of objects into space.


Chair: Squyres, Steven W.

The session speakers were then invited to offer comments. They discussed that these benefits require vast investments from the public sector, and thus, return of investment is

important, highlighting missions such as the European Commission's Copernicus Programme designed to facilitate interoperability between nations and cooperation among institutions; that mitigating the impacts of global warming requires not only monitoring greenhouse gases and climate trends but also complicated cause-effect relationship between climate elements, how current climate models can be improved, how satellites are advantageous because they cover the entire globe, the need for international collaboration for satellite observations given the limited resources available, and how they should promote open and interdisciplinary discussions guided by the SDGs; how positioning satellites are the sources of new businesses, are a pillar for many important activities, such as precision agriculture, position determination, synchronization of operations for banks and power lines, and search and rescue operations, and how coupled with future innovation and progress in AI and robotics, they can lead to more comfortable lives and sustainable environment such as self-driving vehicles, airplanes that can land and take off in harsh weather, and internet access in rural areas; how NASA's observations are critical for understanding how earth resources are changing and could change in the future, how domestic and international collaboration is crucial such as coordination of satellites of various countries, how NASA's Earth Observatory can be used to monitor refugee migration, the role of NASA and capacity development in developing countries, such as monitoring frost damage on coffee crops in Kenya, and how targeting critical needs worldwide and measuring progress is an important way forward; how JAXA has various projects help mitigate and prevent disasters by detecting earthquakes and volcanic eruptions, how it collaborates with JICA to reduce illegal deforestation, and how it has a satellite exclusively designed to monitor greenhouse gas emissions which can contribute to the implementation of the Paris Agreement.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon how emerging countries' wishes to develop their own satellites should not be neglected and the need to work with them in this regard; how the benefits of space research are not felt by the people relative to the size of government investment; how the participation of private companies in space is welcome; how only government and not the private sector can support basic science, which plays a fundamental role, and therefore how agencies such as NASA and JAXA remain relevant; how accumulated data from satellites can identify regions which have problems like diseases and stop them; how satellites will enable the collection of images with improved resolution; challenges such as data mining, access to data, and inadequate links between information and society; how small companies have

a role in environmental monitoring through the development of small-scale satellites but sophisticated science such as Copernicus that can get 3D data can be done by public agencies; the question of monitoring the quality of data of private companies and the role of the public sector; the need for governance related to space debris; whether manned space flight should be left to the private sector because they can accept higher risks; the question of robotics vs. human space flights; whether making Mars a vast outpost for humanity is achievable and how long that will take; and spending funds is worth keeping Earth a habitable place.

Earth Science
Water

[Chair]

El-Beltagy, Adel El Sayed Tawfik, Chair, International Dryland Development Commission (IDDC), EGYPT

[Speakers]

Abel, David, Chairman, Managing Director, VerdeXchange Institute, U.S.A.

Henmi, Masahiro, Director, Technology Center (Water Treatment) and Research & Development Division (Toray Singapore Water Research Center), Toray Industries Inc., JAPAN

Mulligan, Catherine, Director, Concordia Institute of Water, Energy and Sustainable Systems, Concordia University, CANADA

Ohgaki, Shinichiro, President, Japan Water Research Center (JWRC), JAPAN

Oki, Taikan, Senior Vice-Rector, United Nations University, JAPAN

Vierssen, Wim van, Chief Executive Officer, KWR Watercycle Research Institute, NETHERLANDS

Opening Remarks

The chair opened the session by explaining that the effects of climate change, including river water shortage, reduced groundwater, and increasing seawater level, are expected to cause major damage to human settlements on continents, raising issues such as environmental refugees, which will lead to social and political upheaval. He underscored the need to focus on navigating from global to regional to local, as well as a paradigm shift to a more holistic approach to fulfill the goals and actions of the SDGs, the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction 2015-2030.

Chair: El-Beltagy, Adel El Sayed Tawfik

The session speakers were then invited to offer comments. They discussed how effective investment can be promoted for disaster resilience by not carrying out disaster prevention measures separately but rather

integrating them with the construction and maintenance of water infrastructure, giving the examples of the development of drought mitigation and water conservation measures in Fukuoka following its severe drought events, the construction of a new transmission pipeline connected to emergency water supply in Kobe following the 1995 earthquake, and the development of a water system in Yokohama allowing for water treatment to be continued even during an emergency; building a sustainable water system in the long-term through integration of 1) intergenerational societal values, 2) preventing sunk-cost effects, 3) vertical integration in pursuit of an egalitarian society, and 4) horizontal integration, and how a far more integrated water system needs to be designed with objectives centered on the circular economy; how the United Nations University system on the whole is coordinating a taskforce to prepare for the decade of 2018-2028 for water for sustainable development and how a correlation between GDP and access to water can be observed; a new roadmap in California that was developed in response to a drought crisis and how California Water Fix looks at technologies all over the world to solve the problems; the need for large amounts of electricity for water treatment systems, the issue of aging water infrastructure, measures such as anaerobic waste treatment and low-energy systems such as wetlands that may have potential; how to reduce the harmfulness of concentrates in water treatment plants, the integration of membrane systems, concentrate discharge, advanced oxidation process, the importance of wastewater as an energy nutrient, and use of energy units for emergency preparedness, such as small units in small islands that are easy to operate.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon shifting from the supra-national to national scales to regional and local scales and to closed cycles, noting that if solutions are not regionalized, problems will not be solved; how investments in technology should be continued but that political will does not necessarily exist, and the importance of communicating the problems to politicians; absence of food security and how it should be dealt with by trading capacity; how climate change and water is a perception issue, giving the example of how people in California see it as a new normal that people must face whereas in places including Australia, it is a slow change in probabilities; how responses to extreme situations are being put into place in a mechanical way; how rights and responsibilities play out differently across regions in extreme situations that involve the federal government, noting the problem of water rights where water companies have increasing rights and government noting that it is a public right; how addressing these challenges requires changes in technology, society, perception and governance; how wastewater can be used to tackle water shortages; the importance of working with communities, especially if bringing in a new technology, and the need to adapt the technology to that area; and use of small solar units as low-energy systems that can be potentially useful for many applications.

Earth Science
Disaster Prevention and Resilient Society

[Chair]

Hayashi, Haruo, President, National Research Institute for Earth Science and Disaster Resilience (NIED), JAPAN

[Speakers]

Alcántara- Ayala, Irasema, Professor, Institute of Geography, National Autonomous University of Mexico (UNAM), MEXICO

Alexander Augustine, Lauren, Director, Program on Risk, Resilience, and Extreme Events, The National Academies of Sciences, U.S.A.

Douglas, Rowan, CEO, Capital Science & Policy Practice, Willis Towers Watson, U.K.

Koonin, Steven E., Director, Center for Urban Science and Progress (CUSP), NYU, U.S.A.

Tamura, Keiko, Professor, Risk Management Risk Management Office, Niigata University, JAPAN

Opening Remarks

The chair opened the session by explaining that it is difficult to completely prevent disasters, making it paramount to reduce disaster risks. He noted that resilience is a key concept of disaster reduction in the three accords of the Sendai Framework, the SDGs, and the Paris Agreement.

Chair: Hayashi, Haruo

The session speakers were then invited to offer comments. They discussed that addressing the root causes becomes a major challenge since it is dominated by a reactionary response, that the use of technology has been left to engineering solutions such as flood control dams which create a sense of false confidence, that disasters will remain damaging so long as politicians, practitioners, and other stakeholders continue to neglect the understanding of disaster risk as a social construct, that there is an urgent need to incorporate a forensics approach into disaster investigation to promote transdisciplinary studies that are policy relevant and provide policy options, that integrated and transdisciplinary research engaging all stakeholders is needed in light of incorporating disaster risk reduction into development planning and socioeconomic growth, that risk-informed decisions and risk-sensitive territorial planning from local to global scales are needed; that the three accords are international and the disconnect is that the actions and impacts take place at the local level, that actions should be linked with the goal or priority that is driving the community such as tourism, that the alignment of goals, budget, and jurisdiction from the international to local levels can feed into the accords; that the issue is how to get science into legal duties, governance, and fiduciary and financial responsibilities, that unified metrics and a shared methodology to risk are needed, that nothing will change structurally until companies, cities, and others hold contingent capital against risks so that resilience gets awarded, and that integration of methods and systems are needed as witnessed; that it is difficult to tackle the lack of resources and institutional rigor to deal with natural disaster risks, that the effects of some natural disasters such as Hurricane Harvey in Houston are exacerbated by human factors, including poor drainage due to inadequate regulation; that recovery, rehabilitation and reconstruction (RRR) after a disaster offers a great opportunity for communities to make drastic changes to social infrastructure to increase resilience by learning from past and current disasters, while equally important is planning for RRR before a disaster including laws and systems for disaster response so as to achieve prior public consensus.

Discussion

Following the opening remarks, a group discussion was held. The participants noted that disaster resilience is not just about response, that science and technology can help estimate disaster probability and cost but is not doing enough on disaster impact with one of the key reasons being corruption, that insurance is important but gives people a false sense of security, that mobilization of human resources is important for responses; that it is important to focus on a particular risk that cuts across manmade versus natural risks and decipher what science needs to be done; that weather prediction can be done quickly but there is the question of how to get the information to the people and whether they are acting properly; that they need to determine whether to consider disasters and risks in 10-year or 100-year timeframes; that natural disasters are easy to predict but the question is human psychology, that the costs of disasters have to be distributed in a rational way such as building infrastructure in places that would mitigate disaster impacts; that people need to

be incentivized to become implementers, that better visibility is needed for stakeholders at all levels and that it is better if information is put not in silos and "tribal" to stop people from keeping their knowledge within their tribes, and that the inherent nature of failure as humans make them the weakest link in the entire scenario.

Earth Science
Climate Change and Ocean

[Chair]
Lee, Yuan Tseh, President Emeritus, Academia Sinica, TAIWAN [Nobel Laureate 1986]

[Speakers]
Kural, Cem, R&D Director, Arçelik A.Ş., TURKEY
Lochte, Karin, Director, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), GERMANY
Partridge, Simon, Engineering Director, Sonardyne International, U.K.
Rees, Martin, Astronomer Royal and Fellow of Trinity College, Cambridge University; Member, House of Lords, U.K.
Taira, Asahiko, President, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), JAPAN

Opening Remarks

The chair opened the session by explaining that climate change and global warming is not a problem of the next generation but a real and imminent challenge of the current generation.


Chair: Lee, Yuan Tseh

The session speakers were then invited to offer comments. They discussed that the level of urgency attached to climate change impacts depends on various factors including whether or not economists apply commercial-style discounting, that a unique difficulty of motiving CO_2 reductions is that the impact not only lies decades ahead but is globally diffuse, that nations should extend R&D into all forms of low-carbon including renewables and 4th generation systems, that scientists need to influence public opinion while accepting that on the issues of ethics and politics they are citizens and not experts; that the Paris Agreement has given momentum to

carbon neutrality initiatives by governments, companies, and institutes, and that companies are undertaking activities to understand how the ocean will withstand the impact of GHG and CO_2 emissions and how a solution can be created for a carbon neutral world; that while surface terrestrial life has been well documented, there lacks precise documentation on marine life, that there lacks any science framework to consider the integration of the natural and social sciences and humanities, that new research needs to be initiated to understand the impact of human activity on the environment; that most people are more worried about changes on land that are visible as opposed to the non-visible changes in the ocean, that it is difficult to see which species in the ocean we are losing, that climate changes will have major impacts on fishing and the global marine food supply, that understanding of the rapid changes in the Arctic Ocean is necessary to assess the implications for the rest of the world, and that only few countries are currently able to conduct research in the open ocean beyond national jurisdiction while the changing ocean affects all countries, and that the ocean has to be put into better focus for future consideration of climate change, that new technologies for automated systems are necessary to observe this huge part of the Earth system; that knowledge about the ocean is limited, noting that no satellites can penetrate deeply into seawaters and oceans are massively under-sampled, that ocean measurements need to be revolutionized to properly understand how and why the ocean is changing, adding that having instruments that can be left in the ocean for decades is critical because

changes in the ocean take place over decade timescales, and that better coordination of datasets between the science, defense, and commercial worlds is needed, and asked what will enable commercial applications to drive greater density of measurements in the oceans similar to land.

Discussion

Following the opening remarks, a group discussion was held. The participants stated that ocean literacy is needed to communicate what the ocean means to the entire earth system, that international global observation of oceans is critical and that the Argo float was successful because standardization and data sharing benefited all participants, that the next steps may include adding pH sensors, and that global observation can be advanced from the industrial side; that a holistic model of the earth is necessary which integrate social systems, Anthropocene, and human impact and which take advantage of technologies such as AI and deep technologies, that scientists and engineers have a responsibility to help society adapt to the changes; that solutions for addressing the problems of uncertainty related to the ocean may include better integration and combination of modeling sensors as well as the strengthening of fundamental research, and that communication through the press must be improved; that non-traditional solutions to receiving funding for data collection included asking insurance companies, foundations, and oil companies, and that a human medium is essential to communicating the data.

Cooperation in S&T

Competition and Cooperation among Global Industries

[Chair]

Bakker, Peter, President & CEO, World Business Council for Sustainable Development (WBCSD), SWITZERLAND

[Speakers]

Horiba, Atsushi, Chairman, President & CEO, HORIBA, Ltd., JAPAN

Ishikawa, Masatoshi, Dean, Graduate School of Information Science and Technology, The University of Tokyo, JAPAN

Le Gall, Jean-Yves, President, National Centre for Space Studies (CNES), FRANCE

Marshall, Larry, Chief Executive, Commonwealth Scientific and Industrial Research Organisation (CSIRO), AUSTRALIA

Matsui, Mitsuru, Executive Fellow, Corporate Research & Development Group, Mitsubishi Electric Corporation, JAPAN

Wince-Smith, Deborah L., President & CEO, Council on Competitiveness; President, Global Federation of Competitiveness Councils, U.S.A.

Chair: Bakker, Peter

Opening Remarks

The chair opened the session by discussing competition and cooperation among industries for growth in the global economy. He added that this is a relevant topic for STS *forum* because economic models are built on competition, while cooperation in science is the only way forward. From his experience in the sustainable field, the chair added that we live in an era where collaboration is essential. The creation of science-based targets, and increasing them, is a good example of how science is shaping cooperation.

The session speakers were then invited to offer comments. They discussed unprecedented scientific advancement, unforeseen collaboration, and the convergence of fields; the different barriers preventing such cooperation, such as different cultures, cybersecurity attacks, and differences in regulations across regions and countries; the importance of discussing social and ethics issues of some of the new developments and technologies such as AI; the field of emission gas analysis, a sector which is transforming rapidly due to progress in electric battery research, and the fact that cooperation is essential at this stage because of the need to prepare the necessary infrastructure for this new technology; the question of acquiring and cooperating with other companies; how science-driven innovation creates ecosystems where competitors are also collaborators, or an ecosystem of "co-opetition," and how, because science solves impossible problems, it enables an all-new market and all-new values, that could not have existed before. Furthermore, they discussed how cooperation requires a high budget now to turn basic research results into innovation, which leads to important questions such as how to evaluate competition and collaboration in a globalized world, and whether vertical cooperation, among researchers, makers and users, or horizontal cooperation, whereby technologies are shared by competitors, is better. In addition, they touched upon the revolution in the field of space, with the entrance of big data companies and the emergence of new countries in the area; the need for space agencies to adapt to this new context; the importance of international cooperation between space agencies to ensure that they stay competitive; and the emergence of climate change as one important field of cooperation. Finally, speakers also discussed the difficulty of collaboration between industries and academia in science and technology because of their difference of perspective, namely that industries think in terms of market and profit, and academia in terms of contribution to science and education; and the need to discuss how to share intellectual property.

Discussion

Following the opening remarks, a group discussion was held. The participants discussed difficulties to cooperate at the international level because of cultural differences, the importance of establishing a base in other countries that would have the authority to make decisions, and the value of trained members that are fluent in the language and the culture of the targeted country; the importance of discussing ethics and values across countries, the need for international platforms such as the Sustainable Development Goals, the capacity to gather all nations and industries, and the need to involve social scientists in discussions; how to set up new structures of innovation, how to improve innovative research in all industries, and the difficulty to implement horizontal infrastructure because of the reticence to

share information with competitors; the sovereignty of nations in space exploration; cooperation and competition in leading industries; the importance of having different perspectives to solve industrial problems; the difficulty of information sharing even though it could be beneficial to fields such as medical research; the question of whether collaboration is moving from the pre-competitive stage, such as in the lab and at universities, to competitive spaces such as industry; the situation in Singapore which cannot survive without collaboration; the necessity of collaboration between science and industry in the health system; the need for science and business communities to collaborate and build trust with each other; and the clear definition of words such as "collaboration."

Cooperation in S&T
Science and Technology in Developing Countries

[Chair]

Plangsangmas, Luxsamee, Governor, Thailand Institute of Scientific and Technological Research (TISTR), THAILAND

[Speakers]

Anderson, Warwick, Secretary-General, International Human Frontier Science Program Organization (HFSPO), FRANCE; former Chief Executive Officer, National Health and Medical Research Council (NHMRC), Australian Government, AUSTRALIA

De la Peña, Fortunato T., Secretary (Minister), Department of Science and Technology (DOST), PHILIPPINES

Hagan, Julius Kofi, Senior Lecturer, Department of Animal Science, School of Agriculture, University of Cape Coast, GHANA [Future Leader 2016]

Leinen, Margaret, Vice Chancellor for Marine Sciences and Director of Scripps Institution of Oceanography, University of California, San Diego (UCSD), U.S.A.

Piramal, Swati Ajay, Vice Chairperson, Piramal Enterprises Ltd., INDIA

Suzuki, Noriko, Senior Vice President, Japan International Cooperation Agency (JICA), JAPAN

Chair: Plangsangmas, Luxsamee

Opening Remarks

The chair opened the session by raising four important points on the theme of S&T in Developing Countries: S&T policies, specifically clear government policies; infrastructure investment and the establishment of an investment plan; human resources developments, such as appropriate education, researchers' capacity and diversity, and the best use of limited resource; and collaboration with governments and non-government organizations.

The session speakers were then asked to offer comments. They discussed the situation in the Philippines, including the recent

government agenda of promoting S&T as science is considered to contribute to improvement of competitiveness, rural enhancement and human capital; investments in infrastructure focusing on a wide field of institutions such as new research institutes; human resources improvement, such as the shift from a 10- to 12-year education system; and the choice of collaboration partners depending on an established list of common problems and potential benefits. The speakers also spoke about the importance of the development of universities and academia, and the role that national politics of developed countries and international funders should provide in that regard; how to incite international funders to invest in developing countries and the importance to retain researchers; as well as the three key issues in the field of human resources related to S&T in developing countries, which are support from basic education to higher education, networking on the model of a "cooperation system" and international joint research among developed and developing countries, and the need for institutions to establish policy priorities. Furthermore, speakers cited the important role of philanthropy as fourth actors of cooperation, as foundations are able to take risks and to apply learning to a field on a large scale; important challenges facing philanthropy such as working with governments to achieve the necessary skills, and the importance of innovation and skills as the principles that define an operating strategy. They also discussed the contribution that scientific society can make to S&T in developing countries such as scientific meetings and workshops, which is key for scientific network creation; the ways to promote the participation and access of developing countries by reducing the cost of membership of scientific societies or investing in digital technology for publication; and the contribution of scientific societies to the understanding of a wide

number of problems that do not exist in developed countries by bringing foreign scientists together. Finally, they also touched upon the situation relating to S&T in Ghana, specifically how the country is trying to graduate from a lower middle income country to become an upper middle income country, how it needs to take S&T seriously, and the importance of incentive and appropriate public support.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon the need for champions to change the current situation; the necessity of building capacity in other countries; the decline in interest among governments for science for problem solving, and how to make science attractive again; the importance for governments to focus on the Sustainable Development Goals (SDGs); the fact that policy-making depends on the needs of the country and the need to select the right areas in terms of SDGs for funding; the importance of investing in soft infrastructure to support hard infrastructure; collaboration in intellectual property protection; solutions for narrowing the gap that exists between the poor and rich countries; the value of national policies that support the retention of scientists in their countries; the importance of university support from developing and developed countries; the necessity for scientists to network and ensure the transfer of knowledge; creating connections between politics and science and how scientists can influence policies; the need to focus on the solving of national and cross-border issues; the importance of freedom among scientific exchange; the relations between universities, the private sector and government, and the fact that universities are academically rather than commercially oriented and lack trust in the industry sector; the importance for localities to solve local issues; the opposition between regionalization and globalization; and the need to develop regional networks to face common problems.

Cooperation in S&T

Collaboration among Academia, Industries and Government

[Chair]

Mishima, Yoshinao, President, Tokyo Institute of Technology, JAPAN

[Speakers]

Al-Ibrahim, Hamad, Executive Vice President, Research & Development, Qatar Foundation, QATAR

Chan, Tony F., President, The Hong Kong University of Science and Technology (HKUST), HONG KONG

Inan, Umran, President, Koç University, TURKEY

Kawabata, Shigeki, Vice President, Evolving Medical Solutions, Astellas Pharma Inc., JAPAN

Liu, Jonq-Min, President, Institute for Information Industry; President, Industrial Technology Research Institute, TAIWAN

Molloy, Christopher J., Senior Vice President, Office of Research and Economic Development; Distinguished Professor, Dept. of Pharmacology and Toxicology, Ernest Mario School of Pharmacy, Rutgers, The State University of New Jersey, U.S.A.

Subiyanto, Bambang, Acting Chairman, Indonesian Institute of Sciences (LIPI), INDONESIA

Chair: Mishima, Yoshinao

Opening Remarks

The chair opened the session by explaining that collaboration among the triple helix, namely government, academia and industry, in R&D is essential due to the drastic changes brought about by new technologies such as AI and ICT. There is a need to combine different seeds of knowledge to achieve new perspectives, insight and viable solutions for modern issues.

The session speakers were then invited to offer comments. They discussed the importance of considering these actors as an ecosystem even though their responsibilities

and mindsets differ; how problems related to tripartite collaboration often arise because these actors have different definitions of their respective roles; and successful examples of the Chinese government bringing together universities and industries to work on large scale projects. They also discussed the fact that academia, government and industry have different metrics to measure performance, different priorities, and different incentives when engaging in science and technology, and the need for these to be aligned; how excellence can be defined among different stakeholders and how to bring together the right personnel from different sectors; the dilemma of whether education should define the market or the market should define education. In addition, there was mention of issues relating to the dynamic between academia and industries when collaborating in R&D, such as industries asking universities to solve problems and then prohibiting them from publishing their results; the need to carry out collaboration around long-term objectives; and the importance of promoting the hiring of graduates of PhD programs by industry. The speakers also covered the need to create a new health care system in Japan and the importance of academia and industries collaborating at a practical level to find better ways to enhance health care technology, while containing costs; as well as the benefits that Taiwan has enjoyed from the introduction of the technology-readiness level concept, which has allowed the government to invest in projects based on their level of readiness, enhance cross-disciplinary collaboration, optimize the operations of the technology transfer division within a research organization, and facilitate international collaboration. In addition, they touched

upon the practical need for universities to attract financial support from the government and industries, improve their capacity to communicate their goals and results, and to advance industry relationships; the lack of participation by industry in R&D in Indonesia and the recent initiative of the government to stimulate tripartite collaboration through policies to bridge academia and the private sector; positive examples of collaboration in the medical area in Indonesia; and the need for the Indonesian Institute of Science, which has good relations with foreign companies, to do more to foster the support of local companies.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon good models for academia-industry and university-laboratory collaboration; collaboration on specific economically-relevant research topics; the appropriate level of involvement of government in tripartite cooperation; models for industry-university collaboration in developing countries; different visions of the role of each of these actors depending on the country; the importance of fostering dialogue among the three sides and especially the role of academia in these discussions, as it is the most neutral; the difference between the respective language, goals and time scale of each side; the need to develop incentives for companies to work with universities; the need for government to support industries to work across borders with academia; the need to align the incentives of different institutions; the importance of creating shared value in tripartite collaboration; the importance of impact over income; the role and need for intermediaries to facilitate collaboration in national and international contexts; the value in educating policymakers about the benefits of such cooperation; the importance of creating new approaches to managing new intellectual assets; government involvement and its role in investment in research; the three waves of technology and innovation; the role of government as a facilitator in promoting greater understanding; the need to showcase university research to attract partners; the importance of PhD students having a wider perspective to increase their mobility into the three sectors; and the need to cultivate entrepreneurship among young people.

Cooperation in S&T
Science and Technology Diplomacy and International Collaboration

[Chair]

Bourguignon, Jean-Pierre, President, European Research Council (ERC), European Commission, BELGIUM; Honorary Professor, Institute of Advanced Scientific Studies, FRANCE

[Speakers]

Carrero-Martínez, Franklin A., Acting Deputy Science and Technology Adviser to the Secretary of State, U.S. Department of State, U.S.A.

Inaba, Kayo, Executive Vice-President, Gender Equality, International Affairs, and Public Relations, Kyoto University, JAPAN

Krichever, Igor, Director of Skoltech Center for Advanced Studies, Skolkovo Institute of Science and Technology (Skoltech); Professor, Mathematics, Columbia University, RUSSIA

Lassonde, Maryse, Scientific Director, Scientific Direction, Fonds de Recherche du Québec - Nature et Technologies (Québec Science and Technology Research Granting Agency); President, Royal Society of Canada, CANADA

Walport, Mark, CEO Designate of UK Research and Innovation, HM Government, U.K.

Chair: Bourguignon, Jean-Pierre

Opening Remarks

The chair opened the session by stating that science and technology diplomacy should be considered from different angles. One aspect is regional research institutes who engage in extensive international collaboration and strong coordination to work on global projects. Another aspect is the individual researchers. In both cases, there are governmental barriers to the development of joint networks, due to issues such as visa problems.

The session speakers were then invited to offer comments. They discussed the importance of building science capacity among society and the government, especially among

foreign ministries, how science, technology and innovation support the UN's Sustainable Development Goals (SDGs), and how all the different sectors can engage together in science and technology diplomacy. The discussion included details of several initiatives by Japanese universities and agencies to foster collaboration with foreign institutions around the world in order to cooperate on global issues, such as the SDGs and disaster prevention, as well as to help localities to solve regional problems, such as by sending academic experts and researchers abroad. In addition, they discussed the importance of conducting science within an international network to ensure a higher quality of research; the need to ensure greater impact on government and policy makers and encourage researchers to share their findings and publish their results more effectively; the potential of science and technology to benefit national diplomacy, such as in the recent research agreements between Jerusalem, Gaza and Quebec; the different meanings of diplomacy, including official government diplomacy and unofficial interaction and intervention of non-state actors, and their relation to science; mutual contribution of diplomacy and science to one another; the opportunity to facilitate national and mutual economic growth through science and technology; the use of science as a tool for international development or maintaining international relations during conflicts; and the value of the integrity of scientists in international matters. Furthermore, the speakers touched upon how, in the case of mathematics research, not much funding is needed, but it is nevertheless important for mathematicians to share ideas and engage in diplomacy on an individual level; the value in centers organizing international fora; the fact that science and mathematics serve universal goals; and finally, the role of national academy of sciences in science diplomacy was invoked.

Discussion

Following the opening remarks, a group discussion was held. The participants spoke about how science exchange at an individual level can maintain strong interconnections between countries; how the existence of different layers of institutions governing scientific policy can create complex barriers to science and technology diplomacy; how science can deepen collaboration in a wide range of fields; the need for scientists to be more multidisciplinary, such as by performing political functions and being more active in diplomacy; the global responsibility of scientists to solve common issues and their ability to act as peacekeepers; the potential benefits of having scientists as advisors in government and having more scientists in diplomatic delegations; the need to protect academic freedom by offering researchers the opportunity to study abroad; the benefits of conducting exchanges at a multilateral level; how the SDGs can be viewed as a milestone of science and technology diplomacy; brain drain as a negative consequence of international mobility and the need for capacity building and good governance to retain scientists in their home countries; the importance of ensuring mutual benefits as a way to enhance diplomacy; the need to create funding opportunities for young scientists and multidisciplinary funding programs; and the importance of dialogue among different types of institutions to create open science environments.

S&T and Society
Innovation in Society

[Chair]

Kurokawa, Kiyoshi, Chairman, Health and Global Policy Institute; Professor Emeritus, National Graduate Institute for Policy Studies (GRIPS), JAPAN

[Speakers]

Harel, Elchanan S., President and Founder, Harel-Hertz Investment House Ltd., ISRAEL

Liao, James C., President, Academia Sinica, TAIWAN

Miller, Scott E., Deputy Under Secretary, Science and Collections, Smithsonian Institution, U.S.A.

Noyori, Ryoji, Director-General, Center for Research and Development Strategy, Japan Science and Technology Agency (JST), JAPAN [Nobel Laureate 2001]

Stølen, Svein, Rector, University of Oslo, NORWAY

Opening Remarks

The chair opened the session with the declaration, "Innovation is over. Now is the time for disruption." He spoke about disruption leaders like Amazon, Airbnb, and Uber; companies that have an entirely new kind of business model and are global in nature. He asked the speakers and participants to give their input on the new ideas that can shape Japan and other countries in an increasingly uncertain world.

Chair: Kurokawa, Kiyoshi

The session speakers were then invited to offer comments. One topic was the open source model and crowdsourcing, representing new forms of global collaboration that encourage sharing rather than the secrecy of strictly guarded patents of the past. An example is Wikipedia, the most popular information source in the world with an innovative self-correction mechanism. There was also discussion of education and creating a better world through knowledge, as exemplified by Victor Hugo's quote, "Stronger than any army is an idea whose time has come." This led to discussion of innovation of museums, exploring how to leverage knowledge that exists in museums in analog form and deliver it to a world that is increasingly connected. Provision of existing knowledge on forestry and watershed management applied to managing water resources is one way that museums can make an impact. Museums also represent a beacon of authenticity in a world where trust has fallen in many information sources.

The next topic was machine learning and artificial intelligence (AI), which will enable us to achieve superhuman intelligence and activities. However, these technological advances will be accompanied by social challenges that we will face very soon. Although AI will usher in extraordinary productivity and efficiency, adverse social implications such as the replacement of human workers by machines will manifest. The question we must ask ourselves is if our future society is becoming a utopia or a dystopia. As the information age becomes a reality and the current social revolution accelerates at a pace far faster than the Industrial Revolution, it is important to remember that society cannot run on computers and data alone. We must not lose our humanity. We must ensure that ethics guide the impact of science and technology on society, with policies that include the Nordic Model and global cooperation on achieving the Sustainable Development Goals (SDGs).

Discussion

Following the opening remarks, a group discussion was held. A major topic of discussion was emphasizing and implementing both science and social science, balancing the role of the scientist alongside the philosopher. Social issue-driven innovation appropriate for society should be the focus. Although there is no "one size fits all" policy, it was agreed that we should examine and create shared visions of what exactly a desirable society is, not just in terms of technology but also its broader impact. For this, it was brought up that we must find ways to "innovate innovation." Countries should work toward the SDGs and companies should adopt the concept of creating shared value (CSV). In addition, innovation not only encompasses cutting-edge technology, but also utilizing existing technology and bringing it into a new context. Digitalizing and creating new uses for existing knowledge is vital to reap its full benefits.

Another major topic of discussion was unintended consequences of innovation, such as tracking of internet use, that can be used maliciously. We must be equipped to handle these unintended consequences. In addition, new tools are needed to handle the sheer volume of data available in this increasingly complex era. There is a deep need for systemic change, effected through a new kind of platform, in all of society. Changing mindsets, collaborative work, and education are vital for acquiring and implementing new technology.

S&T and Society
Bridging Science and Technology with Society and Politics

[Chair]
Duszyński, Jerzy, President, Polish Academy of Sciences (PAS), POLAND

[Speakers]
Hara, George, Chairman, Alliance Forum Foundation; Special Adviser to the Cabinet Office, Prime Minister of Japan; Intergovernmental Ambassador Extraordinary and Plenipotentiary to the United Nations, JAPAN
Kalyuzhnyy, Sergey, Advisor to CEO, Chief Scientist, Fund for Infrastructure and Educational Programs, RUSSIA
Kishi, Teruo, Science and Technology Advisor to the Minister for Foreign Affairs, Ministry of Foreign Affairs, JAPAN
Sibunruang, Atchaka, Minister, Ministry of Science and Technology, THAILAND
Šucha, Vladimír, Director-General, Joint Research Centre, European Commission, BELGIUM
Young, Kate, Parliamentary Secretary for Science, Innovation, Science and Economic Development Canada, Government of Canada, CANADA

Chair: Duszyński, Jerzy

Opening Remarks

The chair opened the session by recognizing the diversity of discipline and accomplishments of the speakers. He noted that technology has led to many challenges, including the spread of fake news and the necessity of restoring the confidence and trust of the public and governments in science. He stated that he hoped the speakers and participants could help find answers to these challenges.

The session speakers were then invited to offer comments. It was brought up that science and technology are meaningless unless they serve a purpose for society. However, sometimes government regulation can stifle the

benefits of innovation during lengthy testing of safety and efficacy. It was pointed out that it is necessary to work on deregulation in pharmaceutical frameworks to get medication to people with certain diseases who have an urgent need. It was also mentioned that investment in high-tech companies can prove challenging. Research requires money while innovation generates money, but sometimes researchers are not good business people. It is also important to invest in the next generation of scientists. The need for science advice as well as evidence-based policy making is gaining greater importance. Currently, the UN's Sustainable Development Goals (SDGs) is the main agenda in dealing with such needs. It is exactly what bridges science and technology with society and politics. The SDGs also provide opportunities for scientists to have a voice in the policy making process. The government, academia and industry of Japan have started working on the SDGs.

Another session topic was the concept of post-normal science. Politicians make decisions on funding for research, and engaging with them through timing, trust, form, and format are important to influence stagnating policy-making. In addition, restoring trust in science is vital in our post-fact society, and looking at how facts are received by citizens and politicians. This led to a point about rebuilding a lack of trust in politicians, which is important for government technology strategy. It is vital to ensure scientists and researchers are working to solve societal problems, especially in developing countries like Thailand where

governments are striving to reduce the gap with developed countries. Finally, there was a focus on the keyword of trust, in both science and society. Science is integral to good policymaking, and should lead to the jobs of the future, create a better quality of life, and touch all aspects of people's lives.

Discussion

Following the opening remarks, a group discussion was held. One point was that bridging science and technology and politics needs to encompass short-term results and focus on long-term effects. There needs to be a way to balance long-term goals while still showing short-term outcomes to politicians, who need them to keep their jobs. If politicians are unable to fulfill their promises, this weakens public trust both in politics and in science. It was also noted that even though the goals of scientists and politicians are quite different, we need to bridge the gap between scientists and politicians through closer collaboration of academia, business governments and research councils.

Another topic was rationality and values in the decision making process which led to the observation that scientists need to be more proactive. It was also stressed that science and politics have a different time perspective and that science often comes too late. The participants agreed that academia needs to reach out to society through different communication channels and needs to work on communication of scientific uncertainty. Other topics discussed included: researchers' independence, setting national priorities, how governments can keep up with the cutting-edge research, how to provide information-based policy-making, and how to ensure that research is relevant to policy. It was agreed that the SDGs present a profound opportunity to communicate the importance of science and technology to society. While science can be thought of as international and politics as national, the SDGs are an international cause that brings global politicians and scientists together.

S&T and Society
Science, Technology and Engineering Education

[Chair]

Abé, Hiroyuki, Special Counselor to the President, Principal Fellow, Japan Science and Technology Agency (JST); President, The Engineering Academy of Japan, JAPAN

[Speakers]

Haldane, F. Duncan M., Professor, Department of Physics, Princeton University, U.S.A. [Nobel Laureate 2016]

Kolman, Michiel, Senior Vice President, Academic Ambassador Emeritus, Elsevier B.V.; President, The International Publishers Association (IPA), NETHERLANDS

White, Christina Kay, Global Chair, Engineering Education, National Academy of Engineering, U.S.A. [Future Leader 2016]

Winter, Ekkehard, Executive Director, Deutsche Telekom Stiftung, GERMANY

Zajfman, Daniel, President, Weizmann Institute of Science, ISRAEL

Chair: Abé, Hiroyuki

Opening Remarks

The chair opened the session by observing that we must understand and solve increasingly multidisciplinary issues that are becoming ever more complicated. As the boundaries of science, technology, and engineering blur, technical innovation led by universities is vital for addressing global issues. Further, applying the concepts of STEM and STEAM, as well as encouraging creativity and continuing education, are key issues for many countries such as Japan. The chair concluded by asking the participants to analyze education for excellence, education for students, and education for citizens.

The session speakers were then invited to offer comments. The first topic of discussion involved eschewing a hyper focus on university rankings, and examining educational foundations to teach future generations to develop uniquely innovative ideas to be able to give back to society. There is no one way to teach innovation, but one change to make is refraining from teaching students that there is only one problem solution, because in reality there are always multiple possibilities. There was also an introduction of the Grand Challenges Scholars Program, an educational framework in which students examine and find ways to tackle pressing global "grand challenges" through initiatives such as intrapreneurship opportunities, which fosters global citizens with cross-cultural communication skills. Such frameworks are vital for active, blended, and collaborative (ABC) learning.

A further topic was fostering educational excellence, soft skills that cannot be digitalized, and emotional intelligence. Questions to ask ourselves include how to apply STEM and STEAM, how to show students, especially girls, the digital revolution in the making to draw them to STEM, and how to convey to the public the strengths as well as uncertainties of science and technology. As data challenges classical knowledge production, we must examine how to reflect such changes in education. Another topic was the importance of interaction with professors in a world where some might think technology is making them obsolete. At Princeton University, professor guidance and interactive projects are irreplaceable and help students learn to think outside the box. The final topic was the importance of trusted, peer-reviewed content from professional publishers in the age of fake news. The three goals should be truth (including challenging censorship and infringements on academic freedom around the world), effective knowledge transfer (by championing new learning strategies such as active learning), and research into education (identifying how effective learning occurs).

Discussion

Following the opening remarks, a group discussion was held. One point was that the definition for excellent teaching should encompass teaching students that there are always multiple problem solutions, helping students identify the questions that need to be asked, and not punishing failure. Another discussion focused on how people learn in different ways, evidence-based learning, and how to assess the quality of resources. Another main point was the importance of the humanities and its applications in STEM and vice versa. Examining the practical realities of interdisciplinary education, including how funding is distributed, is important. There was a debate on whether teachers are actually needed, which led to an examination of the evolution of teachers into facilitators who help students

interact with and apply knowledge to everyday life, which involves changing the mindset and training of teachers.

Another main focus was on challenges, including challenges in developing countries where millions of people now strive to achieve education, how to teach people to teach themselves with tools like MOOCs, how to trigger soft skills like curiosity, and how to create "portfolios of learning" that incorporate venues like museums in addition to schools. One pressing challenge is the gender gap in science and technology, as well as continuing to pique the interest of younger generations while also encouraging lifelong learning in adults. Discussions also centered on how to reach out to a public that is unhappy with the current situation in education, with suggestions that included putting a public face on science and through publishing.

S&T and Society
Policy Making in Science and Technology based Society

[Chair]
Gutfreund, Hanoch, Executive Committee Chairperson, Israel Science Foundation; former President, The Hebrew University of Jerusalem, ISRAEL

[Speakers]
Gibbs, Doon, Director, Brookhaven National Laboratory, U.S.A.
Hamaguchi, Michinari, President, Japan Science and Technology Agency (JST), JAPAN
Schmidt, Brian P., Vice-Chancellor, Australian National University, AUSTRALIA [Nobel Laureate 2011]
Shin, Sung-Chul, President, KAIST, KOREA
Steen, Tomoko Y., Professor, Department of Microbiology and Immunology, School of Medicine, Georgetown University, U.S.A.

Opening Remarks

The chair opened the session by focusing on the two policymaking goals of ensuring that the products of science and technology are effectively used in society, and facilitating the production of science and technology. Governments achieve this through a complex process of allocation of resources and legislation. Policymakers are challenged by the fact that science and technology are increasingly global, and sometime struggle to convey the usefulness of science and technology to achieve public trust and support. Points to address included scientific advice to policy makers, investment accountability, roles of governments, academia, and industry, and special issues facing developing countries.


Chair: Gutfreund, Hanoch

The first topic involved establishing relationships of trust with governments. Australia National University, for example, works with

policymakers to advance society by supporting scientists and knowledgeable policymakers. Facilitators and listening to the problems of the government are necessary to dispatch the appropriate sources of expertise. Embedding experts in government is vital, such as medical experts in pharmaceutical policy. Challenges lie in balancing short political cycles that demand quick results and long-term goals. A further topic was the importance of an interdisciplinary approach to science and public outreach, with highlighted initiatives including One Health, Bench to Bedside, and the Cancer Moonshot Task Force. The most important point is for scientists to work with government officials and policymakers to disseminate accurate information and ensure scientific literacy.

Another topic was on how policymaking occurs within the US Department of Energy, with an emphasis on partnership and collaboration. The consortium of national lab directors meets by itself and with the DOE to discuss national as well as lab issues, and then contributes by writing white papers, organizing science events, and educating. A further subject included the fact that investment is driven by what society wants, but the risk lies in failing to meet expectations. Thus, new, nonlinear approaches are necessary. For example, the Center of Innovation program of Japan Science and Technology Agency, implemented in 18 universities, seeks to imagine the desirable society 10 years from now, apply "backcasting" to achieve goals, and generate large-scale academia-industry collaboration under one-roof. This has yielded results such as hundreds of patents, large sums invested by industry in universities, and, for example, exploring brain science to reveal the product design choices that excite consumers to satisfy their expectations. The final topic was on the critical factors for scientific evidence, legitimacy, and paradigm shifts. South Korea is now facing an energy crisis with debates about nuclear power, and factual evidence is crucial for the discussion. In addition, government-university-industry collaboration is key. Recently, the role of universities is changing and expanding. The "third mission" of universities calls on them to pursue innovation and enterprise activities, which is being undertaken by the Korea Advanced Institute of Science and Technology and other universities.

Discussion

Following the opening remarks, a group discussion was held. Topics included the challenges of policymaking, including relevance, independence of policymaking without influence, maintaining academic freedom, spreading knowledge, and inclusivity and attracting the next generation to science, technology, and innovation (STI). A practical example of science aiding society was given in the form of the revitalization after the Great East Japan

Earthquake, which involved scientists who helped provide better technological solutions to survivors. One policymaker suggested a change from "science for science" to "science for people," as well as adapting technology to different cultures and ensuring technology makes it to developing countries. There was also discussion of R&D for national interest in countries like Singapore, such as stimulating industrial sectors.

Another point echoed by many was that communication is key and should be fostered by the various stakeholders, with scientists bridging the gap with policymakers, and policymakers helping to bridge the gap between scientists and other disciplines to prevent researchers from working in a vacuum. Scientists should stress to policymakers the importance of evidence-based decision-making, especially given the rise of lobbyists who are influencing policy with third-party interests. Scientists need to convince governments about the importance of STI to push them to invest in it, and the results of funding decisions often comes down to an individual level. Fellows and others with strong scientific backgrounds should become a part of government, and committees and fora for influencing policy should increase, in order to reduce the polarization between government and academia. Finally, scientists should emphasize to policymakers that even if the outcomes of long-term investments seem far-off, they can produce incrementally useful results for society.

ICT
Artificial Intelligence (AI)

[Chair]
Khosla, Pradeep K., Chancellor, University of California, San Diego (UCSD), U.S.A.

[Speakers]
Anzai, Yuichiro, President, Japan Society for the Promotion of Science (JSPS), JAPAN
Bengio, Yoshua, Scientific Director, Montreal Institute for Learning Algorithms (MILA); Full Professor, Computer Science and Operations Research, University of Montreal, CANADA
Kotani, Motoko, Executive Director, RIKEN, JAPAN
Socher, Richard, Chief Scientist, Salesforce; Adjunct Professor, Stanford University, U.S.A.
Tsujii, Junichi, Director, Artificial Intelligence Research Center (AIRC); Fellow, Advanced Industrial Science and Technology (AIST), JAPAN

Opening Remarks

The chair opened the session by briefly discussing the history of AI from being considered useless and receiving no funding to having made major impacts in recent years. Over time, the definition of AI has become largely misunderstood or unknown. As we seek to define what we, as a society, call AI, we need to address the complications that arise along with it as the technology can impact jobs, affect the stability of society, and create other complex ethical questions such as whether or not AI can have emotions and empathy.

Chair: Khosla, Pradeep K.

The session speakers were then invited to offer comments. They discussed the foundation of AI as ESP, which is five-layers of engineering, science, and policy (or priority) and the fact that we cannot foresee the output of AI systems, thereby stressing the importance of establishing an international organization that supports public health and wellbeing;

fears of the robot uprising are unfounded as we are very far from human level AI but we do need to be concerned about its misuse as the technology has current and future impacts on social equality and political stability; how to establish policies that guide AI development towards the betterment of society and how to leverage it to gain more wisdom; how implementing AI into our present organizations requires a dataset, algorithms, and workflow; and how we need to consider the broader issues relating to ethics and moralities that can be created from having autonomous systems without intelligence or what we consider to be common sense.

Discussion

Following the opening remarks, the chair invited the participants to hold a group discussion. The participants touched upon the complexity of defining AI and how its scope has expanded from machine-to-machine interface and human-to-machine interface to include augmented intelligence; the difficulties of transferring a history of social intelligence, self-consciousness and party intelligence into systems that can predict and adapt themselves based on unpredictable events; the potential dangers of an unexpected, but still mathematically approved, AI result and whether or not there should be a standardized test for its regulation; the need for a globalized organization to govern the potential military use of AI; how to build a culture that has confidence in the technology; and the broader ethics

around data handling, ownership, and use. The participants further discussed the potential future of AI by listing where it currently works in our daily lives, the present limitations, and its future application in genomics and genome construction versus genome reading. They further emphasized the need for a new scientific framework to help guide the development of AI intelligence.

The closing public statements touched upon the recurring themes of what intelligence is, how we can prevent biases in AI results, whether or not a machine can ever exceed human intelligence and win a Nobel Prize, and whether or not the science and technology community should be actively influencing governments to avoid the use of AI in military warfare.

ICT
Internet of Things (IoT)

[Chair]

Saito, William H., Special Advisor, Cabinet Office, Government of Japan; Vice Chairman, Palo Alto Networks, JAPAN

[Speakers]

Bradlow, Hugh S., President, The Australian Academy of Technology and Engineering (ATSE), AUSTRALIA

Creese, Sadie, Professor of Cybersecurity, Department of Computer Science, University of Oxford, U.K.

Iwano, Kazuo, CDO (Chief Digital Officer), Emerging Technology and Business Development Office, Mitsubishi Chemical Holdings Corp., JAPAN

Nielsen, Paul D., Director and CEO, Carnegie Mellon University's Software Engineering Institute, U.S.A.

Reps, Mailis, Minister, Ministry of Education and Research, ESTONIA

Opening Remarks

The chair opened the session by stating that the topics around the Internet of Things (IoT) were quite broad in that they cover autonomy, networks and coverage, data standards, computing at brain scale and security. These topic areas are driven and influenced by the 3Ms: Markets, Mother Nature, and Moore's Law. The cost and proliferation of sensors, as well as the new reality of networks has rapidly changed the world and requires us to take a new approach to cybersecurity and data.

Chair: Saito, William H.

The session speakers were then invited to offer comments. They discussed the role of cybersecurity as the fundamental enabler of the internet and not the other way around; the diversification of security as it progresses beyond personal authentication and personal data protection to one that may need to be

governed due to risks to nations and regions; how the younger generation has a completely different relationship with security; and how the early education around cyber-hygiene can have additional societal benefits such as the ability to define solutions for establishing an unknown future. They assessed the current state of IoT defining it as being more of a craft than a science which is evident by its current state of fractionalization; and the importance of networks, data platforms, the integration of endogenous and exogenous data, and human brain computation capabilities as keys for its continued maturation. IoT, in its current broad technological state, is within a natural evolution of human development but where it is different from other technological advancements is with its extension of temporal relationships. This brought the discussion to the importance of creating decision boundaries and parameters in a dynamic environment with potential scenarios such as the impact and risks of militarization of IoT being important factors for establishing a verification of trust and its many dimensions within present and future autonomous systems. In addition, IoT as a model of society and people was discussed within the terms of how the establishment of a new identity can shape future services based on wisdom computing, thereby creating a software defined society.

Discussion

After the opening remarks the participants held group discussions. They covered the differences between industrial IoT and consumer IoT; the evolved role of data as "the new oil" having first been an encapsulated solid, then fluid, and to its current gaseous state; the

challenges, potentials and ethics of teaching autonomous systems to self-govern and self-defend; and how IoT can affect business models, value chains and societies. The discussions included topics around social responsibilities and who should be responsible for the global regulation, governance, and standard creation for IoT; how to balance the oversight of the industry without negatively impacting future opportunities and growth; the Data, Information, Knowledge, Wisdom, and Decision model as it relates to the ongoing development of IoT; and how the cultural differences around the understanding and tolerances of data and IoT adds to the challenges of a global standardization. The discussion also shifted to the philosophical question of "what is wisdom" as a question to ponder as we guide the evolution of IoT as a community.

The chair recapped the session by saying: data is now defined as a gas; we need to consider the social responsibility, ethical, moral and privacy impacts of IoT; we need to balance opportunity and risk as it relates to continued evolution; both infrastructure and standards are critical; that insurance will have a future role to play; and that we as the community need to work together to establish a global framework for advancement.

ICT
Big Data

[Chair]
Serageldin, Ismail, Founding Director Emeritus, Library of Alexandria, EGYPT

[Speakers]
Ataka, Kazuto, Chief Strategy Officer, Yahoo Japan Corporation, JAPAN
Donnelly, Peter, Director, Wellcome Centre for Human Genetics; Professor of Statistical Science, University of Oxford; CEO, Genomics plc, U.K.
Hamilton, Marc, Vice President, Solutions Architecture and Engineering, NVIDIA Corporation, U.S.A.
Krishnan, Ananth, Chief Technology Officer, Tata Consultancy Services Limited, INDIA
Sugiyama, Masashi, Director, Center for Advanced Intelligence Project, RIKEN; Professor, Department of Complexity Science and Engineering, The University of Tokyo, JAPAN
Yeh, Nai-Chang, Professor of Physics, Department of Physics, California Institute of Technology (CALTECH); Fletcher Jones Foundation Co-Director, the Kavli Nanoscience Institute, U.S.A.

Opening Remarks

The chair opened the session by discussing the exponential boom of data in recent years and how this will affect the future of academics, businesses, governments, and individuals. The amplification of change created from the diversity, complexity, and volume of big data requires us to think differently than before. Though data capacity has increased in recent years, data interaction and application is still nascent with many unknowns which we need to consider. The chair reminded that with great unknowns comes great risk, as well as great opportunities.

Chair: Serageldin, Ismail

The session speakers were then invited to offer comments. They discussed the successful applications of data and machine learning in natural language translation and image understanding ; how big data coupled with machine learning will provide powerful outcomes and applications; how increased data dimension complicates analysis by requiring even more data; the importance of the academic and governmental agencies to take action around frameworks and regulations for new data governance; the importance of engaging with the public sector around big data education to establish skills and to create understanding or acceptance; the opportunities of big data in the field of genetics and genomics; the impact of big data on the daily roles of software developers, social science, and computational science; the need for a super-Moore's Law or a Tensor's Law; and data content discrepancies. The speakers also discussed the functions and influences that big data has on enterprises, businesses, and global economies. Specifically, they touched upon the potential imbalances created from the extreme concentration of American and Chinese data and technology companies who have advantages in the size of the population using the common languages, governmental policies, cost of data processing, and the availability of talent; the changes in the persistent and transient attributes of data across boundaries; the differences between big and small data; and the consideration of establishing big data as a new market commodity. In addition, they discussed the need for data objectivity; identifying the purposes and intent for using data; how to leverage either guided analysis or exploratory analysis to derive knowledge from data; and potential disruptive technologies that could expand the capabilities of artificial intelligence (AI) and Big Data.

Discussion

Following the opening remarks, a group discussion was held. The participants covered the meaning of "big data" and what it means to academics for whom it must be checked against facts and reality, as well as the public sectors for whom it may be tailored to perceptions; the ethics and ownership of collecting, accessing, and managing data; the difficulties around the anonymization of data; the virtues of data transparency; deep learning and data processing; the use of simulation versus confirmation scientific approaches in big data application; and the tipping point where data morphs from a listening or reporting element to an aid in behavioral modification. The group also discussed the future role of data within and upon society. They discussed how citizens of different countries could be empowered through education; the importance of cross-industry collaboration to bring datasets and data analyses together; the potential disparities that could be created across humanity; and that millennials have a different understanding and, therefore, acceptance of data than prior generations.

The chair closed the session by noting that social sciences as we knew it is and will be changing with the proliferation of small and big data, machine learning, and AI.

ICT
Cybersecurity

[Chair]

Fuchs, Alain, President, French National Centre for Scientific Research (CNRS), FRANCE

[Speakers]

Ekert, Artur, Professor, Mathematical Institute, University of Oxford; Professional Fellow, Merton College, U.K.; Director, Centre for Quantum Technologies, SINGAPORE

Goto, Atsuhiro, President, Institute of Information Security (IISEC), JAPAN

Harris, Duncan, Vice President, Security Assurance, Global Product Security, Oracle Corporation, U.K.

Pierre, James St., Deputy Director, Information Technology Laboratory, National Institute of Standards and Technology (NIST), U.S.A.

Tangau, Wilfred Madius, Minister, Ministry of Science, Technology and Innovation (MOSTI), MALAYSIA

Tokuda, Hideyuki, President, National Institute of Information and Communications Technology (NICT), JAPAN

Opening Remarks

The chair opened the session by quoting former US President Obama who said that the cyber threat is one of the most serious economic and national security challenges society faces. He then reminded the participants that cybersecurity spans a large variety of scientific domains encompassing cryptography and other theoretical foundations, hardware security, software security, network security, and privacy. All of these aspects are interrelated and need to be taken into account to secure systems which are increasingly heterogeneous, connected and distributed. Cybersecurity is a domain where it is particularly important to have practitioners and theorists work hand and hand. To be able to address the future challenges of having a trustworthy cyberspace, the sine qua non

Chair: Fuchs, Alain

condition will be to rely on a cybersecurity science with strong scientific foundations and developments. This will not be achieved without taking into account the everyday attacks and other practical issues of cybersecurity. Within our world of real threats and attacks, we need to also remember that cybersecurity science is a broad spectrum which is also aiming to become a mature field, by developing sane fundamental building blocks.

The session speakers were then invited to offer comments. They discussed how Malaysia has proactively invested to prioritize, advise, and establish cybersecurity policies and innovations; how the classification of IoT devices, as managed and non- or poorly managed, create different challenges as non-managed devices are opened to the greatest risk; the fact that specialists across the different cybersecurity disciplines will be required to protect global events, such as the Tokyo 2020 Olympics and Paralympics from cyber attacks; the real possibilities of quantum computing systems, the risks that they create related to current encryption methods, and the potentially great benefits of using quantum cryptography and other quantum methods to secure information and crypto-systems;; the need for crypto-systems that are immune to quantum attacks; how the rapid proliferation of embedded *nora*-IoT (ownerless devices) in our everyday life puts us at greater environmental risks of large scale attacks; the need for international standards and the leveraging of A.I. to enhance security, and the fact that IoT risks can manifest in real, physical attacks; the hope

for a future where cloud computing services could play a role in automating the completion of simple security checklists; how to reassure consumers that cloud and IoT can be trusted; and the complicit role of human behavior (specifically human inaction) in cybercrime.

Discussion

Following the opening remarks, a group discussion was held. The participants continued the topics and themes identified by the guest speakers, including how human tendencies towards simplicity becomes a barrier to good cyber-hygiene; how human immaturity, with regard to security, is a weakness to be overcome when attempting to thwart cybercrimes; the advent of quantum computing and the impact of the paradigm shift it heralds; and how secondary or tertiary factor authorizations can be used to prevent everyday attacks. The discussion further included national security and the inclusion of validating information as a component of facts; providing cyber-hygiene and security as general education; how security is a social engineering problem as much as it is a science engineering one; and the idea that if we are to reduce the security risks, we need to change the perception that it is solely a technical issue when, in fact, it is mostly a social one.

Cities and Mobility
New Transportation and Mobility Systems

[Chair]

Rübig, Paul, 1st Vice-Chair, Science and Technology Options Assessment (STOA), European Parliament, BELGIUM

[Speakers]

Ahmad, Raslan, Senior Vice President; Head of MIGHT International, MIGHT International, Malaysian Industry-Government Group for High Technology (MIGHT), MALAYSIA

Drees, Joachim, CEO, MAN Truck & Bus AG / MAN SE, GERMANY

Jackson, Keoki, Chief Technology Officer, Corporate Engineering, Technology and Operations, Lockheed Martin Corporation, U.S.A.

Kirloskar, Vikram S., Vice Chairman, Toyota Kirloskar Motor Private Limited (TKM), INDIA

Suzuki, Norihiro, Vice President and Executive Officer, Chief Technology Officer, and General Manager of Research & Development Group, Hitachi, Ltd., JAPAN

Opening Remarks

The chair opened the session by explaining that during the session they would be discussing how technology changes lives in mobility, sustainable natural resources, the challenge of creating mobility for billions of people, new advances in mobility and fuel such as battery technology, the impact of artificial intelligence on mobility systems such as continuous driving to lessen the environmental impact of stop and go, and perfect life – the impact science and technology can potentially have on increasing QoL, amongst other topics.

Chair: Rübig, Paul

The session speakers were then invited to offer comments. They discussed the ongoing challenges of the commercial vehicle industry such as electrification in terms of the impact on public transport in large metropolitan areas and the technologies that will make it feasible such as new battery technology, creating safe systems for autonomous driving as a foundational platform in order to build strong business cases, interoperability and cooperation among businesses and new technologies in the area of digitalization and connectivity; congestion challenges in India and achieving a balance of providing mobility while also taking care of the environment, implementation issues in terms of introducing public transport systems to large metropolitan areas and the policies that support these initiatives, the potential of big data in having an impact on assisting the introduction of mobility systems, increasing mutual respect and trust between the average citizen and the government as a starting point to sort out mobility issues; the challenges of emerging economies such as Malaysia in providing data infrastructure to support new mobility systems and balancing that with environmental considerations, bringing together public and private sectors to work efficiently and collaboratively and ensure that common goals are set and met, the role that science education places in educating the public to accept new technology systems; the importance of sharing a vision drawn from real data, achieving sustainability by providing real value in an ecosystem that achieves energy and resource efficiency through a synergy of technologies such as big data analytics, AI and IoT to deliver reliability, availability and time & cost value to users as well as cost benefit to providers; the need for hand-in-hand development of mobility technology and infrastructure, new aircraft design to optimize manufacturing, engine, air drag, and fuel usage capabilities, and new automated technologies currently being developed for airplane, helicopter, and ground transportation systems.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon how society and transport are intertwined, Japanese centric challenges in society such as declining birth rates, re-thinking the way people flow in and out of large urban centers, collaboration and integration between companies and governments, communicating mobility visions of the future to the public; vehicle sharing, traditional and future motor systems and solutions, city and urban planning, governance challenges when there are overlapping areas of responsibilities, hyperloop technology, demand responsive mobility solutions; education of society and politicians on topics related to science and resources, public and private consensus on infrastructure development, the need for more efficient data mining in addressing mobility challenges, integrated development of systems in cars to focus on increasing QoL for passengers; awareness of increased demand of transportation as technology advances, the environmental impact of new mobility technologies, finding the right mix of transport technologies unique to city circumstances, understanding scalability of technology solutions before moving forward with implementation, governance and regulation; growing railway transport infrastructure in China, new fuel technologies and initiatives for public and private mobility, and the importance of swiftly disseminating new mobility technology information to the public and policy makers to increase general understanding.

Cities and Mobility
Smart Cities

[Chair]

Emura, Katsumi, Executive Vice President, Chief Technology Officer and Member of the Board, NEC Corporation, JAPAN

[Speakers]

Creecy, Barbara, MEC for Finance, Gauteng Province, Johannesburg, SOUTH AFRICA

Khoo, Teng Chye, Executive Director, Centre for Liveable Cities (CLC), Ministry of National Development (MND), SINGAPORE

Mori, Hiroo, Director and Executive Vice President, Mori Building Co., Ltd., JAPAN

Schomberg, Richard, Vice-President, Smart Energy Standardization, EDF Group; IEC Ambassador, Smart Energy, International Electrotechnical Commission (IEC), FRANCE

Sumantran, Venkataramani, Chairman, Celeris Technologies, INDIA

Tyler, Nick, Chadwick Chair of Civil Engineering, Department of Civil, Environmental & Geomatic Engineering, Faculty of Engineering Science, University College London (UCL), U.K.

Opening Remarks

The chair opened the session by discussing the background of the session, noting that the world's urban population was anticipated to increase approximately 30% by 2050, with the population of those living in cities to reach 80%, requiring new and innovative approaches to deal with increases in resource consumption. He stated that optimizing global efficiency by reducing energy consumption in urban areas, as well as implementing environmentally friendly technologies, where two of several methods to help develop smart cities.

Chair: Emura, Katsumi

The session speakers were then invited to offer comments. They discussed the biological stress of living in cities and the need to create civilized, highly social environments to promote inter-human communication, using smart technologies to enhance connectivity

between people regardless of age and background; smart city design taking into account long-term planning for sustainability, advanced technologies such as augmented reality to assist urban infrastructure development, setting up mechanisms to promote the continued development and evolution of urban centers, examples of smart city deployment in France and Dubai that measure noise pollution, movement of people, and citizen experience in order to identify mechanisms that should be focused on in the long-term, the collective need to open city data for analysis and comparison purposes; the transformation of Singapore into a global first world country/city using integrated urban systems approaches to urban development, balancing conflicting themes such as economic development and green spaces when creating livable spaces, the importance of science, technology, and good governance to integrated approaches to city development, the essential need for regulatory bulwarks to analyze new technologies before they are harnessed by urban centers, the importance of platforms such as the STS *forum* and the World Cities Summit to assist in the sharing of best practices; economic friction resulting from inefficient mobility in cities, the increased autonomy and independence of the city, environmental concerns in discussing mobility, personalization and heterogeneity in mobility and finding better ways of addressing a larger population, physical and digital connectivity providing ways to link mobility options together, the importance of policies, regulation, and planning in city design; the developmental and sustainable challenges of creating smart cities in developing countries such as South Africa, initiatives taken in South Africa such as raising educational levels among disenfranchised populations, work placement and training initiatives generated through collaboration between the public and private sector, building broadband networks to increase connectiveness among populations, creating innovation systems through partnerships with universities and development of innovation hubs, running boot camps for emerging entrepreneurs, and regulatory challenges at the provincial and national level; competition between mega cities in the face of increased globalization, the changing and diversifying view of citizens with regard to urban environments, the importance of face to face communication and collaboration in generating innovation despite advances in communication technology, the need for smart cities to be resilient, and the importance of leadership in making advanced, safe, and effective smart cities a reality.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon the importance of taking both a top-down and bottom-up approach to leadership and education, the role of science and technology in creating smart cities; Kant's view of space

and time in the context of what a smart city is and what it can deliver, the importance of bringing people together in smart cities, anticipating the changing needs of citizens over time, the efficiency of city operations, building cities with disabled and challenged people in mind; the need for smart cities to be physically safe, avoiding segregation and ghettos in smart cities, creating spaces for work and pleasure within cities to minimize transportation and increase overall QoL, the key issues of food and water supply, cybersecurity and integrity in terms of how people are monitored in cities, how cities can embrace disruptive technologies; the importance of the unique circumstances and identity of individual cities in smart city development, smart city best practices; city dashboards that are open to all citizens, and the essential nature of economic and social inclusion for cities.

Statement

1. The 14th Annual Meeting of the Science and Technology in Society *forum* took place from October 1 to 3, with the participation of nearly 1,400 global leaders in science and technology, policy-making, business, and media from nearly 80 countries, regions, and international organizations.

2. In 2017, the STS *forum* launched a new initiative to increase the participation of business leaders and we included a special CEO (Chief Executive Officers) lunch meeting in our Annual Meeting program. Nineteen CEOs from prominent global companies attended. We also had a CTO (Chief Technology Officer) Meeting, which gathered close to 40 CTOs and heads of research, as well as a special lunch for heads of Foundations.

3. The Future Leaders Program, introduced in 2015, has further expanded, with close to 140 young leaders under age 40 from business and academic institutions, who had a special dialogue with most of the 15 Nobel Laureates present at the Annual Meeting. This occasion was particularly well received by both the future leaders and the Nobel Laureates.

4. The STS *forum* also held workshops in Delhi, Brussels, and Bali, Indonesia. We will continue to build on and expand the network we have established to further address the opportunities and challenges facing humanity from the long-term viewpoint.

5. During the STS 14th Annual Meeting, the following points were highlighted.

Energy, Resources and Environment

6. Achieving a sustainable low-carbon society was recognized to be an objective not just in the developed world but also worldwide, particularly in the fast-developing economies. Science and technology is key to attaining this goal but social and economic solutions are also needed. Climate change mitigation is essential for sustainable development in harmony with nature. The interconnected issues of food, water, and energy must be solved through science and technology, but energy policy must also be a component which can contribute to addressing this agenda. In this context, renewable energy plays a more important role in the best mix of energy, although nuclear energy as a low-carbon energy source should also remain an important option under strict conditions of safety, security, and non-proliferation.

7. Beyond mitigation, there must be adaptation and increased resilience in societies that will suffer from the impact of climate change and extreme events. We need to enhance the collection, storage, analysis, and deployment of scientific knowledge on space, earth, oceans, and water in order to devise appropriate policies and programs, nationally and locally. Knowledge from the humanities and social sciences combined with the natural sciences and making the best use of ICT should be deployed to make human society more resilient to the damage brought by disasters and extreme environmental changes.

8. While the world's population is expected to increase before peaking at a high level, this globe's resources are finite. World leaders, whether in government or industry, should consider changes in population and its regional distribution to deploy energy and food reflecting this appropriately. Food production under difficult conditions will require the application of the best of science–including GMOs–to produce more food more efficiently. With urbanization accelerating, smart cities and sustainable human settlements with smaller environmental impact and better quality of life for citizens are needed. These environments can be created by carefully designing systems, deploying new materials and new technologies, and making better use of innovations in mobility and energy systems.

Life Sciences and Health Care

9. Progress in genome engineering and advanced medicine has the potential to improve human health. The accomplishments of R&D in the life sciences should be available for the benefit of all of humanity, subject to certain ethical guidelines. Environmental factors such as Climate Change and air pollution as well as unhealthy diets, habits and lifestyles negatively impact health, and should be confronted by sustained public education. At the same time, the fight against infectious disease is a global mission. We must build an international system to deliver health care to all parts of the world with the cooperation of WHO and other organizations.

10. Healthy aging is becoming a key issue for our societies. In addition to the use of personalized and preemptive medicine, creating more comfortable surroundings for the aged can contribute to healthy aging.

Digitized Society

11. The Internet of Things, Big Data, and AI, combined with robotics and autonomous systems, will not only radically transform our lives but also change the production process and the nature of economic activity. The impact of this on employment must be taken into account. The benefits of progress in these ICT-related fields should enable people in developing countries to start new businesses with minimal resources. But the deployment of these new technologies challenges many aspects of privacy and security. New approaches are needed to alleviate the new and emerging risks of ICT.

Research and Innovation

12. STEM education in schools, as well as for the public at large, is essential for nurturing innovation and promoting sustainable development. Special efforts must be deployed to nurture the next generation of scientists. Policy-making and business decisions based on a sound knowledge of science and technology are of more significance than ever. High-quality science programs are needed to interest and inform the public about the current status and the emerging issues of science and technology.

13. University-based research, both curiosity-driven and applied, and education, with government support and the involvement of private businesses, should play an important role in developing nodes for promoting innovation in society. Government, academia, and business must work together for growth and sustainable development in the global economy as well as at the national level.

Cooperation in Science and Technology

14. Enhancing open innovation requires collaboration between academia, business, and government. In that context, mobility of researchers and engineers between conventional sectors (academia, industry, and government) as well as across countries is essential.

15. There are many aspects to international cooperation in science and technology. Cooperation between different scientific communities in various countries, or in some areas, can allow large-scale research, and cooperation between developed and developing countries is essential for development. Science diplomacy should include the active participation of not only diplomats but also researchers, engineers, and business leaders, to produce beneficial cross-border solutions.

16. We look forward to meeting here again next year. We agreed to hold the 15th Annual Meeting of the STS *forum* in Kyoto from Sunday, October 7 to Tuesday, October 9, 2018.

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