16th Annual Meeting

STS *forum* 2019

Summary

October 6, 7 and 8, 2019

Kyoto, Japan

Science and Technology in Society *forum*

Summary of STS *forum* 2019

STS *forum* 2019 - 16th Annual Meeting Program

October 5-8, 2019

Plenary Sessions | Concurrent Sessions | Invitation Only

October 5, 2019 (Saturday)	
10:00-18:30	**Registration at the Grand Prince Hotel Kyoto** (for all STS *forum* participants)
18:00-20:00	Networking Plaza [New Hall]

October 6, 2019 (Sunday)					
	8:30	Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)			
100	10:00-11:00	Opening Plenary Session 100: **Science and Technology for the Future of Humankind [Main Hall]**			
101	11:00-12:00	Plenary Session 101: **Sustainable Society [Main Hall]**			
	12:00-13:40	Lunch and Networking Time [Sakura]			
102	13:40-14:40	Plenary Session 102: **Lights and Shadows of Energy and Environment [Main Hall]**			
	14:40-14:50	Break			
103	14:50-16:50	Energy **Renewable Energy and Management Systems [Room K]**	Life Sciences **Healthy Aging and Preventive Medicine [Room B-2]**	Engineering and Innovation **Industrial Innovation [Room J]**	Environment **Adaptation to / Mitigation of Climate Change [Room H]**
	16:50-17:20	Networking Time (Coffee Break)			
104	17:20-18:20	Plenary Session 104A: **Science and Technology Education for Society [Room A]**			
105	18:20-21:00	Cocktails and Official Dinner [Event Hall]			

	12:00-13:00	Young Leaders Network [Sakura]
	13:00-15:00	Dialogue between Young Leaders and Nobel Laureates [Sakura]
	13:30-17:50	Regional Action on Climate Change (RACC11) [Room D]
	12:30-15:30	8th Global Summit of Research Institute Leaders [Room C-2]
	14:00-16:40	Kyoto Symposium [Venue: Heartpia Kyoto]

		12:00-13:00 CEO Lunch Meeting [Room 103]	12:00-13:30 CTO Meeting [Room E]	12:00-13:30 University Presidents' Meeting [Room A]	12:00-14:40 S&T Ministers' Lunch and S&T Ministers' Roundtable [Annex Hall]
		Cooperation in S&T **Science and Technology in Developing Countries [Room C-1]**	S&T and Society **Policy Making in Science and Technology based Society [Room C-2]**	ICT **IoT and Cloud in Society [Room B-1]**	Social Infrastructure **Advanced Transportation Systems [Room G]**
		Plenary Session 104B: **Science and Technology in Business [Main Hall]**			

October 7, 2019 (Monday)

	7:30	Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)					
200	9:00-10:10	Plenary Session 200: **AI and Society [Main Hall]**					
	10:10-10:30	Break					
201	10:30-12:30	Energy **Action for Net-Zero Emissions [Room K]**	Life Sciences **Microbiome and Health [Room B-2]**	Engineering and Innovation **New Engineering Technologies [Room J]**	Environment **Marine Environment for Sustainable Society [Room H]**		Cooperation in S&T **Collaboration among Academia, Industries and Government [Room C-1]**	S&T and Society **Innovation Ecosystem [Room C-2]**	ICT **Cybersecurity and Connected Society [Room B-1]**	Social Infrastructure **Population and Urbanization [Room G]**	
	12:30-14:00	Lunch and Networking Time [Sakura]						12:30-14:00 Funding Agency Presidents' Meeting [Room E]	12:30-14:00 Academy of Science Presidents' Meeting [Room 104]	12:30-14:00 Academy of Engineering Presidents' Meeting [Room 103]	12:30-14:00 Head of Foundation Meeting [Room 509A]
202	14:00-16:00	Energy **Future Prospects of Global Energy Mix [Room K]**	Life Sciences **Advanced and Precision Medicine and Bioengineering [Room B-2]**	Engineering and Innovation **Robotics and Society [Room J]**	Environment **Environmental Change and Risks of Health [Room H]**		Cooperation in S&T **Science and Technology Diplomacy and International Collaboration [Room C-1]**	S&T and Society **Information and Communication in the Digitalized Society [Room C-2]**	ICT **Utilization of Big Data [Room B-1]**	Social Infrastructure **Agriculture, Food and Water Security [Room G]**	
	16:00-16:30	Networking Time (Coffee Break)									
203	16:30-17:40	Plenary Session 203A: **Delivering Healthcare to the World [Room D]**					Plenary Session 203B: **Basic Science, Innovation and Policy [Main Hall]**				
	17:40-18:00	Move to Kenninji Temple (shuttle bus provided from ICC Kyoto to site)									
204	18:00-20:00	Special Buffet Dinner at Kenninji Temple					20:30-22:00	Council Meeting			

October 8, 2019 (Tuesday)

	8:00	Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)
300	9:00-11:00	Plenary Session 300: **Key Messages from Concurrent Sessions [Main Hall]**
	11:00-11:30	Networking Time (Coffee Break)
301	11:30-12:20	Closing Plenary Session 301: **Development and Sustainability for the Future of Humankind [Main Hall]**
302	12:20-13:30	Farewell Buffet Lunch [Swan]

	8:00-8:45	General Meeting

Table of Contents

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

Akimov, Maxim, Deputy Prime Minister, Government of the Russian Federation, Russia

Colwell, Rita R., Distinguished University Professor, Center for Bioinformatics and Computational Biology, University of Maryland College Park; Professor, Johns Hopkins Bloomberg School of Public Health; former Director, National Science Foundation (NSF), U.S.A.

Uchiyamada, Takeshi, Chairman of the Board, Toyota Motor Corporation; Chairman, Council on Competitiveness - Nippon (COCN), Japan

Opening Remarks

Mr. Koji Omi, Founder and Chairman, Science and Technology in Society *forum* (STS *forum*); former Minister of Finance, welcomed the participants to the 16th annual meeting of STS *forum*. Mr. Omi expressed his sincere appreciation to all the participants for attending the meeting, as well as the support of the sponsors of the STS *forum*. He then stated that while science and technology have brought about benefits for mankind, they also come with potential threats to society. These are the lights and shadows of science and technology, and leaders from around the world and from different fields must discuss such issues, with a truly long-term vision. In addition, the turbulent global conditions make the holding of such discussions at STS *forum* more vital than ever.

Chair: Omi, Koji

Key issues include balancing economic growth and sustainability, the importance of nuclear energy provided its safety, security and non-proliferation are guaranteed, and the

ever-expanding application of AI technology such as in healthcare and finance. There are also major topics in life sciences, such as the human microbiome and preventive medicine.

The fundamental concept of STS *forum* continues to be to strengthen the lights and to control the shadows of science and technology, while focusing on new areas pioneered by scientists. STS *forum* also believes in fostering the next generation of leaders through its Young Leaders Program. Furthermore, STS *forum* promotes the participation of women. Additionally, it has been conducting various outreach activities to raise its global profile. For example, it held workshops in Singapore, New Deli, and other cities and plans to hold new ones in Mexico City and Moscow.

Abe, Shinzo

STS *forum* is in its 16th year. It has grown from a mere conference to a global movement, encompassing leaders from around the world. STS *forum* is an opportunity to deepen networks and it is hoped that participants will hold in-depth and meaningful discussions that contribute to a better future for mankind.

Mr. Shinzo Abe, Prime Minister of Japan, emphasized that science and technology make the world a better place, and called on the participants to reaffirm the important role science and technology can play. Nonetheless, more can still be done.

Japan recently hosted TICAD7, inviting heads of state from all over Africa to discuss growth. It also hosted the G20 Summit. At both meetings, science and technology was discussed. TICAD7 confirmed the importance of science, technology and innovation for achieving the Sustainable Development Goals, echoing the views of STS *forum*.

Meanwhile, the G20 leaders pledged to reduce the amount of new pollution from marine plastic litter to zero by 2050. At the same time, they recognized the continued importance of

Akimov, Maxim

plastic for society. What is needed is not the shunning of plastic, but better management of waste. Japan will support developing countries in the management of waste, recovery of marine litter, innovation, and empowerment. Among these efforts, particularly critical is innovation, such as the engineering of microorganisms that can store polymers for the manufacture of biodegradable plastics.

Around the world there is a trend of being anti-this or anti-that, including being anti-plastic or anti-growth. Instead of rejecting a particular idea or technology, it would be more constructive to fill in the gaps. For this, science and technology is and will continue to be essential.

Mr. Maxim Akimov, Deputy Prime Minister of the Russian Federation, noted the rapid pace at which the world is changing, highlighting advances in digital technologies and the impact on businesses and governance. Furthermore, employment structures are changing as well, in response to the demand for new skills. Technologies also contribute to the management of resources and pollution.

At the same time, digital technologies can also come with unprecedented global threats. These can only be tackled with international cooperation in science and technology, such as international data-sharing protocols and collaboration in governance. Russia has started programs in digital development, bringing together industry, academia, and government to address long-term issues. Russia invites the cooperation of other countries in these efforts.

In addition, Russia is promoting e-government systems. It has also developed broad rapid response networks. Russia hopes to use AI and other digital technologies to make government systems more efficient, and tackle issues such as resource shortage or aging societies. Furthermore, Russia is promoting bilateral cooperation with Japan, a leader in science and technology, and Mr. Akimov suggested that a series of workshops could be held in cooperation with STS *forum* in Skolkovo next summer.

Dr. Rita R. Colwell, Distinguished University Professor, Center for Bioinformatics and Computational Biology, University of Maryland College Park; Professor, Johns Hopkins Bloomberg School of Public Health; former Director, National Science Foundation (NSF), began by commending Chairman Omi for his vision and his contribution to science and technology, and to mankind. She also expressed her belief that STS *forum* acts as a global ministry of science and technology that benefits global society.

Colwell, Rita R.

Dr. Colwell then reflected on the history of scientific research and the work of researchers from her generation. The challenge today is to analyze massive data sets in a wide range of fields, such as the universe and the human microbiome. It is necessary to integrate these datasets and elicit fundamental principles from them.

Uchiyamada, Takeshi

At the same time, it is necessary to foster the next generation of researchers, who will work with social behavioral scientists and neuroscientists to promote interdisciplinary research to tackle the complex challenges facing the world. It is hoped that the discussions of STS *forum* will inform and guide the next generation, which faces such formidable challenges.

Mr. Takeshi Uchiyamada, Chairman of the Board, Toyota Motor Corporation; Chairman, Council on Competitiveness - Nippon (COCN), spoke about the promise and potential of hydrogen-based societies. Climate change threatens to destroy the Earth. Urgent measures are needed. Hydrogen-based societies are one potential solution. Japan has a vision of establishing a hydrogen-based society. Japan, the United States and Europe are committed to achieving such societies.

Companies in a wide range of industries in Japan are working towards realizing a hydrogen-based society. Similar efforts are occurring worldwide, led by the Hydrogen Council. Toyota emphasizes the importance of hydrogen for reducing CO_2 emissions and has rolled out fuel cell vehicles. Nonetheless, it is taking time for hydrogen to take hold. Cost and regulation should be reduced and revised. Hydrogen needs to be made more affordable and demand for it increased. Investment is also necessary.

Toyota will work to increase hydrogen demand, including by increasing fuel cell vehicle production, spreading fuel cell technologies to commercial vehicles, starting to provide to others not only completed vehicles but also its systems based on vehicle electrification technologies, granting royalty-free licenses on its approximately 23,700 patents for vehicle electrification-related technologies including fuel cell technologies, and starting to use hydrogen also within its plants. In addition, one of the world's largest hydrogen production facilities is currently being built, with completion set to coincide with the holding of Olympic and Paralympic Games in Tokyo in 2020.

Sustainable Society

[Chair]

Holliday, Jr., Charles (Chad) O., Chairman, Royal Dutch Shell plc, Netherlands; former Chairman of the Board, Bank of America; former Chairman and Chief Executive Officer, DuPont, U.S.A.

[Speakers]

Ernkrans, Matilda, Minister for Higher Education and Research, Ministry of Education and Research, Government Offices of Sweden, Sweden

Sugawara, Isshu, Minister, Ministry of Economy, Trade and Industry (METI), Japan

Komiyama, Hiroshi, Chairman, Mitsubishi Research Institute, Inc., Japan

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

Opening Remarks

Mr. Charles O. Holliday, Jr. spoke about the energy transition. The current energy system is a good one, but it must make a transition in response to future needs. The energy system has undergone many successful transitions to date. Much like the transformation brought about by the discovery of oil, new discoveries have the potential to revolutionize the energy system. At the same time, they could also bring new hazards.

Chair: Holliday, Jr., Charles (Chad) O.

Mr. Holliday then highlighted the three Ts that will be key to the coming transition. The first is “technology,” which has been central to all past transitions. The second is “time” or the lack thereof for keeping up with targets for tackling climate change. The third is “trust.” Greater trust is needed in and among government, business and academia.

Finally, Mr. Holliday shared a lesson from the lunar landing. He highlighted a statement made by Buzz Aldrin after the landings, about the important role played by every single person involved, who were determined that they would not let the mission fail. The same kind of determination is required of all of us.

Ms. Matilda Ernkrans also shared a lesson from the lunar landing and the message of the astronauts from the mission, who photographed the Earth and emphasized the necessity of protecting our beautiful planet. Sweden is aiming to be the first fossil-free state in the world. This will require investment, in collaboration with business and academia, both nationally and internationally. It will also take policymaking to bring this all together. Sweden is one of the leaders in national investment in R&D.

Swedish industries and universities are making progress towards making Sweden more sustainable. This includes world-leading research in energy-storing batteries, excellent in cancer and antimicrobial resistance, and development of techniques for the production of steel without carbon emissions. Sweden also has many programs for promoting collaboration. Moreover, it is the mission of its universities to collaborate with broader society.

A key factor in discussions about research and sustainability is research freedom and bottom-up research. This reinforces the integrity of research and will combat resistance against scientific facts. Furthermore, greater gender equality is needed. Societal challenges cannot be overcome with only half the population. Sweden is implementing efforts to promote the advancement of women in science and technology, as well as to support non-EU students studying in Sweden.

Lastly, Ms. Ernkrans called on all countries to work together for a sustainable future.

Mr. Isshu Sugawara began by noting his keen awareness of the importance of sustainability. He explained that, shortly after being appointed as minister, he had to deal with the widespread damage and blackouts caused by a typhoon that struck Japan. Unless societies tackle climate change urgently, and reduce the frequency and impact of natural disasters, it will not be possible for them to be sustainable.

Three initiatives will be key to these efforts: hydrogen, carbon recycling and green finance. Hydrogen is a clean energy source that can be used in a wide range of industries. Carbon is not only a danger, but can be a useful resource, such as for fuel. Hydrogen and carbon

technologies can be game-changers, but their cost must be reduced. Japan has announced plans to have 10,000 hydrogen stations and 10 million fuel cell systems within 10 years. Furthermore, Japan will encourage collaboration and build a center of research for carbon recycling. Green finance is critical to promoting economic growth and environmental protection, and Japan will lead efforts for finance innovation for a sustainable future.

To close his remarks, Mr. Sugawara called on all participants to come together, pool their wisdom, and work towards a sustainable society.

Dr. Hiroshi Komiyama believed that the Tokyo Olympic and Paralympic Games will be a showcase of sustainability. For example, all the metal used in the medals have been recycled from old electronic products. Steel from iron scraps has been used to construct many stadiums. Similarly, the medal podiums will be made from recycled waste plastics.

In the 21st century, most underground resources will have been abandoned and the world will shift to renewable energies and urban mines. In addition to recycling, reusing, and reduction, upscaling will also occur.

Harmony between society and nature is essential for a sustainable society. Japan has worked hard for and succeeded in overcoming the pollution brought about by its rapid economic growth. The ecosystems of rivers and bays have almost been restored. This demonstrates the meaning of sustainability from the perspective of nature.

The Olympic and Paralympic Games will not only embody sustainability, but also diversity. They will involve people from a wide range of backgrounds and demonstrate the importance of diversity for the sustainability of society. A sustainable society is one that is affluent and enables people to achieve self-fulfillment, without adversely affecting the planet. It is hoped that the affirmative actions of people in the Games will signal a change in human behavior and pave the way to a sustainable future.

Dr. Tim Hunt presented a biologist's perspective on the issue of sustainability. Being a biologist, he is acutely aware of the history of life on Earth. The first pollutants were in fact the first aerobic life that emerged on Earth. When reflecting on that, it raises the idea that perhaps the extinction of the human race may not be such a bad thing, at least not for the planet.

Dr. Hunt also shared discussions he had held with younger researchers. He admitted that the future seemed quite bleak to him. That said, there are others who are optimistic about the future, because of their belief in the power of human ingenuity. The responsibility of tackling the problems society faces will be largely up to the efforts of future generations.

Discussion

Dr. Holliday asked Ms. Ernkrans to comment on how Sweden is promoting research freedom.

Ms. Ernkrans explained that it is important not just to do research by consensus but allow researchers to work on a wide range of topics. It is also necessary to support researchers, particularly at a time when researchers can come under threats from society. While it is hoped that researchers' work will contribute to tackling the issues of society, Ms. Ernkrans did not feel the need to pressure researchers to do so, as researchers tend to become aware of these problems before politicians do.

Dr. Hunt felt that it is essential to balance basic research with research targeted at specific problems facing society.

Ms. Ernkrans agreed on the need for balance, while pointing out that researchers need to be given the room to make mistakes.

Dr. Komiyama thought that there is a lack of a direct interface between citizens and academia. He felt that more outreach needs to be done to help citizens understand the role of basic research.

Dr. Holliday then asked Mr. Sugawara to share more details about Japan's carbon recycling initiatives.

Mr. Sugawara shared the Japanese initiative for carbon recycling referring to Osakikamijima in Hiroshima Prefecture, where a Center of Research has been set up. At the center, various technologies for carbon recycling, including efficient CO_2 capture from power plants are being developed and in-flow of companies and researchers to the center is promoted. These efforts are supported by the government with the promotion of open innovation, and based on the government's initiatives, the private sector's voluntary action is also encouraged.

Next, Dr. Holliday asked Dr. Hunt to elaborate on his thoughts about the impact of humans on the Earth.

Dr. Hunt pointed out that if there were only very few humans on Earth, the CO_2 emissions we produce would not be enough to harm the planet. He suggested that existing economic models are based on ever-growing populations and labor forces. Perhaps humankind needs to consider ways to break free from this model.

Ms. Ernkrans highlighted the importance of cross-disciplinary research to tackle sustainability issues, expressing her belief that humans have the ideas and the guts to overcome these issues.

Dr. Komiyama also pointed out the importance of diversity for a sustainable society, and called for greater efforts to harness the power of women and young people in particular.

Dr. Hunt asked Ms. Ernkrans how Sweden has been so successful in promoting gender diversity.

Ms. Ernkrans said that Sweden also faces its own challenges and needs international collaboration to tackle them. She then explained that during and after WWII, there was a great need to rebuild Europe and a lack of labor force, so Swedish women, who had long been active in the labor force domestically, participated in these efforts. In addition, Sweden made political decisions to enable both men and women to take part in the labor force, such as by developing childcare systems. Nevertheless, there are still political forces in Sweden that oppose these efforts. It is also important to have men who support the gender issue.

Lights and Shadows of Energy and Environment

[Chair]

Murray, Cherry A., Director of Biosphere2 Institute and Professor of Physics, University of Arizona; Benjamin Peirce Professor of Technology and Public Policy and Professor of Physics, Emerita, Harvard University, U.S.A.

[Speakers]

Dabbar, Paul, Under Secretary for Science, United States Department of Energy (DOE), U.S.A.

Okamoto, Hiroshi, Vice President, TEPCO Power Grid, Inc., Japan

Al-Khowaiter, Ahmad O., Chief Technology Officer, Technology Oversight & Coordination, Saudi Arabian Oil Company, Saudi Arabia

Bednorz, J. Georg, IBM Fellow Emeritus, IBM Zurich Research Laboratory, Switzerland [Nobel Laureate 1987 (Physics)]

Serageldin, Ismail, Founding Director Emeritus, The Library of Alexandria, Egypt

Opening Remarks

Dr. Cherry A. Murray explained that the session will tackle the issue of the growing use of energy and the effect on the environment. As economies around the world have grown, so too has mankind's consumption of energy. There are many lights to global development, such as moving people out of poverty, but also shadows, such as the emission of pollutants and greenhouse gases.

Chair: Murray, Cherry A.

It is difficult and expensive to eliminate our reliance on fossil fuels. Moreover, this will take a long time. If we do not adhere to the Paris climate change targets, global temperatures will rise by five or possibly even seven degrees by the end of the century, alongside global sea level rise.

However, technological advances, as well as the approaches advocated in the Sustainable Development Goals, offer hope. Nevertheless,

implementing such changes will be highly disruptive.

Mr. Paul Dabbar opened his remarks by pointing out that the US Department of Energy (DOE) has a long track record of scientific discovery. The DOE operates 17 institutions encompassing 60,000 researchers. It promotes open, merit-based research and scientific partnership. It also believes that research should not be used for political means.

The DOE is increasing scientific research funding and believes that the world is in a golden age of innovation. Six fields in particular are the focus of the DOE's funding: advanced and sustainable energy, AI, quantum computing, bioengineering and genomics, advanced mobility, and space exploration.

The DOE also has a track record of promoting mission-driven science and innovation. Significant advances have been made in energy, in terms of cost, efficiency and emissions. Great progress is also being made in energy-storing batteries.

Society must continue to grapple with the lights and shadows of science and technology and STS *forum* remains an important venue for doing so.

Dr. Hiroshi Okamoto began by recalling the recent typhoon that hit the greater Tokyo area, causing damage to houses and infrastructure such as power distribution facilities, causing massive outages. The mission of power companies is to maintain electricity and to restore power as soon as possible in the case of outages.

Not only in Japan but also around the world, energy infrastructure is being affected by natural disasters and climate change. Such infrastructure needs to be made more resilient. In addition, decarbonization is essential for achieving a sustainable society, which requires efforts on the demand and supply sides.

Recent advances in decentralized energy technologies, such as renewable energy and energy storage solutions, offer great potential. TEPCO is investing in such technologies in the hopes of contributing to a convenient and safe society, with access to energy for everyone. They are the key to achieving carbon-free societies.

Nevertheless, these technologies alone may not be enough to achieve the targets in the Paris Agreement. A wide range of technologies and options is essential. Advanced nuclear,

carbon capture and moonshot technologies, such as nuclear fusion or space solar power generation, will also become important. It is hoped that the private sector will also invest its funds in such technologies.

Mr. Ahmad O. Al-Khowaiter spoke about the challenge of addressing the world's growing energy needs in a reliable and affordable way, while ensuring a sustainable environment that can be passed down to future generations. The light of energy is that it has lifted millions of people out of poverty. Like the light of a lightbulb, it can often be taken for granted. At the same time, all lights cause shadows. In this case, the shadow is the carbon emissions that contribute to climate change.

There is consensus on what needs to be done. The key question is how it should be done. We need a paradigm shift in our economic models, which are currently based on limitless resources and limited consumption. We need a circular carbon economy. Besides the classic three Rs (Reduce, Reuse and Recycle), we need a fourth R: "Remove."

Mankind will continue to use fossil fuels, but we need to complement them with renewable energy, reliable and affordable energy storage systems, carbon capture and storage, and technologies that actively remove carbon. Moreover, we need to be confident that we can achieve the necessary breakthroughs in science and technology. In addition, the economics also need to make sense and governments should set up the appropriate frameworks for encouraging investment in the right technologies. Additionally, these frameworks must be

set up through international collaboration. Only then can we grow the necessary solutions for combating climate change.

Dr. J. Georg Bednorz pointed out that although there is clear consensus on the need to reduce the emissions of greenhouse gases, the inadequate results are sobering. Substantial changes in the infrastructure of the entire energy sector are required.

One area is the transport and distribution of energy. Alternative solutions are needed, such as superconductive wires, which would enable the transfer of large amounts of electricity at higher transmission efficiency, with almost no losses. Superconducting technology can also be applied to other parts of the energy sector, such as motors and generators, for example in wind turbines.

In addition, a move to green electricity and a hydrogen-based society will be important for tackling energy and environmental issues. Hydrogen-fuel-cell vehicles are being promoted in Japan. Similar fuel cells could power superconducing motors in electric aircrafts which would greatly reduce the emissions of air travel. Hydrogen could also be used to cool superconducting transmission lines.

The development of new technologies is often left to the initiative of small and medium enterprises. However, new technologies are often met with skepticism by established enterprises. The superconducting industry is prepared to provide solutions, but users remain reluctant to be the first movers. Leaders and decision-makers need to take risks and lend their support for extended testing of new devices under real conditions. Otherwise, new technologies will be stuck at the prototype stage and not be taken up by society.

Dr. Ismail Serageldin stated that economic growth brings with it greater energy consumption, and this has been primarily from fossil fuels, which produces greenhouse gases. So far, this has increased significantly in the last 25 years, while renewable and nuclear energy have failed to significantly reduce fossil fuel use. Human society is standing at a precipice, and yet it still seems reluctant to take the necessary actions. Leaders around the world continue to make the same empty promises, without acting to fulfil them.

We have all adopted a target of zero net emissions by 2050 to keep global warming to under 2 degrees. Given the lack of progress to date, indeed, fossil fuel use has even increased in the past decade, what justifies the belief that fossil fuel use will be reduced to

zero by 2050? Furthermore, the factors that drive increased energy consumption, such as economic and population growth, continue to grow.

Climate change will gravely affect the poorest and most vulnerable people in the world. This will also cause mass migration and the displacement of huge populations. Emissions control and adaption measures are urgently needed, particularly in less-developed countries. New technologies are needed and the right incentive frameworks are required for bringing them to life. Even then, it is not clear that this will be enough to solve the problem. If it is not, other solutions should be explored and it would be worthwhile to consider, if not implement, geoengineering solutions.

Discussion

Dr. Murray noted that several panelists advocated negative carbon solutions and asked for their comments.

Dr. Serageldin pointed out that carbon cycle economies are more promising than carbon capture technologies. Nevertheless, what is ultimately needed is to dramatically transform the lifestyles of people in most nations in the world.

Mr. Al-Khowaiter believed in the importance of setting up the correct economic incentives to allow effective solutions to grow as quickly as is needed. Recent progress in reducing the cost of direct carbon capture technologies are also promising. If mankind can establish virtuous cycles of production and value, miraculous achievements may be seen.

Mr. Dabbar disagreed with Dr. Serageldin and believed that carbon capture will make a difference. Advanced nuclear technology, energy-storage solutions and renewable natural gas technologies could also make a great impact. There is a large pipeline that offers reason for hope.

Mr. Al-Khowaiter believed that stationary carbon capture technologies are commercial today.

Dr. Bednorz did not dislike carbon capture technologies, but thought that this is dealing with the problem after the fact. He wanted to start at the origin of the problem and fix that. He also said that societies should not focus only on the emission of CO_2 but also other more dangerous gases.

Dr. Serageldin did not believe that the current efforts of mankind are adequate. More active efforts and new technologies, including geoengineering, are required. STS *forum* is designed for holding such discussions.

Dr. Okamoto believed in the potential of the application of carbon capture and storage but noted that we need to consider the risks and benefits if we start commercial scale application.

Dr. Murray said she liked the idea proposed by Dr. Bednorz of using hydrogen to cool superconducting transmission lines. At the same time, she pointed out that hydrogen is mildly explosive and cautioned that such safety considerations need to be taken into account.

Dr. Bednorz clarified that hydrogen is explosive in some critical concentrations in air, and liquid hydrogen at normal pressure is safer than pressurized hydrogen.

Dr. Serageldin pointed out that no fuel comes without risk.

Science and Technology Education for Society

[Chair]
Arthur, Michael, President and Provost, University College London (UCL), U.K.

[Speakers]
Maex, Karen, Rector Magnificus, University of Amsterdam, Netherlands
Gonokami, Makoto, President, The University of Tokyo, Japan
Oxtoby, David W., President, Executive, American Academy of Arts and Sciences, U.S.A.
Maesincee, Suvit, Minister, Ministry of Higher Education, Science, Research and Innovation (MHSRI), Thailand
Hagiuda, Koichi, Minister, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

Opening Remarks

Prof. Michael Arthur opened the session by stating that University College London is a globally-engaged institution with a mission to make a positive global impact and nurture students to become global citizens. He emphasized that the session was a valuable opportunity to explore how to develop and apply disruptive technologies in a way that derives benefits for society.


Chair: Arthur, Michael

Education has the potential, increasingly, to become the divider of our age. However, research and education institutions are here to serve all of society, and should not be a polarizing factor in an unequal world. Disruptive change has great potential for positively transforming society, but can also exacerbate existing divisions. Developing and applying technologies that benefit society should be our focus going forward.

Prof. Karen Maex introduced the ideas in the Netherlands on approaching education. Science and technology are transforming society, necessitating education that enables

us to positively handle them. As social changes occur at an increasingly accelerated pace, universities should combine science and technology education with the humanities from the first year to equip students with the right knowledge. Furthermore, the idea of "education for jobs" has a changing meaning because we do not know the jobs and careers of the future.

It is clear we need a new approach. There is much red tape at universities with little flexibility allowed for changes. To address this, the University of Amsterdam works to create better programs that enable students to tackle problems from different perspectives and work in teams. These programs are highly popular among students because they recognize the type of knowledge they need in our changing society. Engagement with society, industry, and government is also a key aspect here. University research also needs to consider the context of results within society.

Prof. Makoto Gonokami noted the important role of universities in global change. Rapid ICT development in the current Fourth Industrial Revolution gives us the opportunity to positively change society, but it can also increase disparities. For a fair future and tackling goals such as the SDGs, it is clear that technological achievement is not enough. It is important to design three things appropriately: science, technology and innovation; social systems; and economic mechanisms.

We also need to consider the state of our planet. This entails safeguarding our global commons, in other words, the planet resources in both physical and cyber space that are becoming increasingly intertwined. Sustainability in cyberspace has a large impact on the real world. We need to work together to save our global commons, creating a sustainable global ecosystem with inclusive economic growth so no one is left behind. Universities are the perfect platform for this, as different stakeholders can work together to create an inclusive future. The University of Tokyo is determined to become a platform for such collaboration, fostering students who will lead us to a better future.

Dr. David W. Oxtoby stated that the American Academy of Arts and Sciences has experts from across the United States and the world addressing significant issues, including energy and the environment, science and technology, and education. He stated that he would stress science education that includes greater emphasis on active learning as well as the next generation of scientists receiving training in humanities and ethics.

The recently-completed Commission on the Future of Higher Education examined three challenges facing higher education, including improving the learning experience to produce lifelong learners in the 21st century. Higher education institutions need to focus on active learning and enabling students to apply the skills they learn in the classroom to real life. It was found that students with applied active learning experiences in undergraduate education were twice as likely to be engaged in their work. Despite the real-world benefits of active learning, only one third of U.S. students have opportunities for it. Ironically, science often provides less opportunities for active learning.

Scientists increasingly need training in ethics to do their jobs properly as ethical challenges continue to rise to the forefront. To develop both "soft" and "hard" skills, they need ethical and communication learning imparted by humanities education.

Dr. Suvit Maesincee stated that we are passing through a sea of change into an age of extremities. To create a better world, we must consider how to reinvent science and technology education. The focus should not just be on knowledge and skills, but also the right mindset.

The future should be one that seeks to eliminate imbalances. Dr. Maesincee emphasized the 4 Ws for this: human wisdom, social wellbeing, environmental wellness, and economic wealth. We need to use science and technology education paradigms not just for business but also for a better society. Instead of competitive production and consumption, such

education should produce collaborative models. Thailand is pursuing such initiatives to create a better society and a better world.

Mr. Koichi Hagiuda noted that the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is the "ministry of creating the future." Science and technology are changing our lives, and technologies, such as AI, robotics, and self-driving cars, can solve issues like depopulation in rural areas. Society 5.0 should be a new era in which all people can live comfortably in a society that highly integrates physical and cyber spaces. In the era of Society 5.0, we need to foster personnel who can create innovation by adapting to change.

MEXT developed a policy for education required for Society 5.0, including the importance of using advanced technology on the primary and secondary education stage. At the higher education stage, it is important to cultivate human resources with advanced judgment and creativity, and we need to make higher education more accessible. Japan decided to reduce tuition and provide students of low-income households with scholarships so they can also pursue education regardless of their household income. In addition, MEXT works on enhancing the recurrent education and improving its social reputation and recognition so people can prepare themselves for new challenges at every age.

Mr. Hagiuda also introduced Japan's 5-year KOSEN system for junior high school graduates. The KOSEN system aims to foster industrial engineers with practical and creative technical skills. It is gathering attention from foreign countries and expanding overseas.

Discussion

Prof. Arthur asked the ministers to comment about the importance of humanities vs. Science, Technology, Engineering and Mathematics (STEM). Dr. Maesincee said that they are both important. In Thailand, the Ministry of Higher Education, Science, Research and Innovation was newly created to combine science and humanities to address societal issues. Mr. Hagiuda stated that basic education including humanities is important for enhancing science and technology, and it is crucial that scientists acquire basic academic skills in not only STEM, but humanities.

Q&A Session

A member of the audience asked who should bear the cost of bringing the value of education to society, especially lifelong learning.

Prof. Maex stated that in new fields like AI, agreements can be made between universities and industry as education is mutually beneficial.

Prof. Gonokami said that digital transformation means that economic value is changing from things to knowledge. In this era of change, we have the chance to reformulate higher education into a global public asset, and make a sustainable economic system for it.

Dr. Oxtoby said that the burden in the U.S. is on students due to high tuition, but it ought to be shared with the government as well as the companies that benefit from that education.

Dr. Maesincee stated that education is an investment in people, and human capital is the most important asset of the 21st century. We thus need to think about education in terms of return on investment and as a public good.

Mr. Hagiuda introduced Japan's recent policy to make nurseries free, as well as the start of scholarships for higher education in April 2020. This will reduce the gap between low and high income households for pursuit of higher education.

Another question was how to measure future skills and accreditation systems. Prof. Arthur noted that this is currently a challenge in the U.K, including teaching quality and student satisfaction.

Another question was about the difficulty of ethical education for young engineers.

Prof. Maex stated that it is important to contextualize ethical issues when asking students about them.

Another question asked about training plans for new technologies in society.

Dr. Oxtoby cited the book Robot-Proof that asserts that education should be redesigned to prepare people for a world where robots and AI will do many tasks. We need to consider what can be done better by machines and what can be done best by humans such as creative thinking.

Another question was about decreasing humanities education at the University of Tokyo, as well as plans to expand KOSEN more within Japan, as well as globally.

Prof. Gonokami said that liberal arts have been taught in the first and second years at the University of Tokyo since the educational reform after the World War II and stressed the importance of humanities.

Mr. Hagiuda stated that KOSEN has been implemented in Japan for 60 years. Many Japanese manufacturing companies have senior staff who are graduates of KOSEN. There has been international interest about KOSEN including from Kenya, Thailand, and other countries. KOSEN should also be further expanded in Japan to develop human resources.

Another question was about how to teach science to humanities students.

Prof. Arthur emphasized having students work with scientists on problem-solving projects.

Science and Technology in Business

[Chair]
Williams, Keith E., President and Chief Executive Officer, UL Inc., U.S.A.

[Speakers]
Yamanaka, Shinya, Director and Professor, Center for iPS Cell Research and Application (CiRA), Kyoto University, Japan [Nobel Laureate 2012 (Physiology or Medicine)]
Gopinathan, Rajesh, CEO and Managing Director, Tata Consultancy Services Limited (TCS), India
Kristoffersen, Helle, President, Strategy-Innovation, Total S.A., France
McKinnell, Henry A., Chairman Emeritus, Pfizer Inc., U.S.A.
Sirilertworakul, Narong, President, National Science and Technology Development Agency (NSTDA), Thailand

Opening Remarks

Mr. Keith Williams opened the session and spoke about the progress of digital technology within the context of certification. Testing and certification technology advancements will radically change the way products are designed and enter the market. Similar transformations across a variety of industries and areas will disrupt their application to society and the world.

Chair: Williams, Keith E.

Dr. Shinya Yamanaka spoke about his optimism regarding the future of mankind in terms of technology. We are uniquely positioned to optimize new technology to address today's challenges. However, science and technology can be a double-edged sword, and therefore requires a responsible approach. For example, while stem cell research should be able to help address and cure chronic diseases, the same technology could be used to hurt society. Therefore, we must find a balanced medium from a social point of view to approaching questions of privacy and ethics.

Mr. Rajesh Gopinathan stated that digital technologies were collapsing traditional industry definitions, and driving the organization of individual enterprises into ecosystems. He noted that while computer technology initially drove simple efficiencies in the workplace, its omni-presence in our public and private lives has shifted the paradigm of customer-business relations from a product-centric view to that of a value-centric, purpose-driven view. The shift in technology and customer expectations requires horizontal collaboration, between industries, to deliver on value propositions of "purpose." This transformation will benefit society tremendously by aligning businesses closer to human needs.

The ethical challenge for businesses going forward will be of "should it" rather than "can it" be done, when looking at technological advancements such as automation. Businesses will have to ask themselves what the purpose of their existence is from a social and moral POV. This approach will not necessarily be detrimental to technology, and business leaders must work with technologists and academia to achieve an ideal balance.

Mrs. Helle Kristoffersen then discussed science and business in the energy industry. The gas industry has been disrupted by recent emerging technologies such as shale gas and oil, shifting global alignments and geopolitics. Decarbonization is imperative for nations and companies and is a focus of NGOs, governments, industry, and academia. However, energy is a key condition for human development. Energy helps fight poverty, develop industry, and raise living standards. Responding to the daunting challenge of "more energy, less carbon" is the task of global society, not simply industry. Promoting low carbon energy sources such as natural gas, renewables, storage, biofuels, and capturing carbon through CCUS (Carbon capture and storage) can help offset global warming in the short-term. De-carbonizing our economies will be difficult but must be accelerated, including by putting a price on carbon. In the long-term we require major breakthroughs in technology to expedite the effort to save our planet.

Dr. Henry McKinnell spoke about frameworks for analysis of science and technology. Basic science and understanding must be translated into a language understandable for the public. Ideally this will drive governments and businesses to prosper and drive innovation. Educational opportunities for businesses can be one important mechanism for ensuring this success. For example, regarding privacy, corporations must work for society and all stakeholders and not just stakeholders. Succeeding in such an environment will be a difficult challenge and some businesses will succeed where others will fail. Over time and with open discussion between government, research, and business, we will find success.

Dr. Narong Sirilertworakul spoke about the rapid consolidation of technologies and disruption in industry. Old barriers to entering markets and industries no longer exist – such as exemplified in the automobile industry with Tesla Motors. New media technologies such as social networks and application platforms have disrupted journalism and hospitality industries respectively. Technology has changed the way companies do businesses, delivering their products to new markets and different audiences. However, there is a double-edged sword to advancements in science and technology. The same platforms and technologies that provide flexibility can also lack regulation and safety, adopted to cause harm and damage. Government and society must work together to protect society and ensure progress without destruction.

Discussion

Mr. Williams asked about the differences between physical and data security.

Mr. Gopinathan answered that physical security has traditionally been provided by individual governments, while data security requires global level support, trust, and collaboration to create a robust and safe platform.

Dr. Yamanaka commented that big data can be useful for disease prevention, but also pose a threat to mankind. Finding a good intermedium between sharing and protecting will be a big challenge for society.

Mr. Williams asked about the relation between data and pharmaceutical development.

Dr. McKinnell expressed his belief that data security issue would require solving across multiple industries. Furthermore, he noted that there were no specific challenges or advantages held by the pharmaceutical industry.

Mrs. Kristoffersen added that not just customer data, but industrial data could be used to improve the environment, as well as collaborate with other industries to improve society. Both information and awareness of its purpose is required for progress – for example in the gas industry we use data to help protect our workers from on-site accidents.

Mr. Williams then asked about data restriction across borders and the barriers it creates for smaller nations and companies.

Dr. Sirilertworakul answered that data hoarding was not beneficial. The advantage of cross-boarder sharing of data is that it is mutually beneficial, which is why its in everyone's interest to share data freely.

Mr. Gopinathan commented that while large countries will have competitive advantages initially, well thought out regulation may help address the issue and level the playing field.

Closing Remarks

Dr. McKinnell closed the session by noting his belief that the primary objective for businesses was to continue focusing on what they do best. However, the strategy must be shifted towards looking 10 years ahead and creating value for all stakeholders in society, and not simply shareholders. A shift in thinking and recognition that the definition of success is can no longer be measured traditionally, but must also be measured in the way businesses are perceived by employees, customers, and society is important. This is a license to do business, which is issued by society. Solving the puzzle, he closed, is the biggest challenge businesses must face in the coming years.

AI and Society

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

[Speakers]
Suresh, Subra, President, Nanyang Technological University (NTU), Singapore
Pisano, Valérie, President and CEO, Mila - Quebec Artificial Intelligence Institute, Canada
Anzai, Yuichiro, Senior Advisor, Director of Center for Science Information Analysis, Japan Society for the Promotion of Science (JSPS), Japan
Etzioni, Oren, Chief Executive Officer, Allen Institute for Artificial Intelligence, U.S.A.
Ottersen, Ole Petter, President, Karolinska Institutet, Sweden
Meyerson, Bernard S., Chief Innovation Officer Emeritus, IBM Corporation; CEO, 4IRAdvisors, U.S.A.

Opening Remarks

Prof. Dr.-Ing. Matthias Kleiner believed that, more than any other technology, AI offers greater potential for transforming the way we lead our lives in disruptive ways. We therefore need social debate about AI, which has the potential to change society for the better, or exacerbate existing problems. It is necessary to maximize the potential benefits, while mitigating the negative effects.


Chair: Kleiner, Matthias

Dr. Kleiner then introduced some questions for consideration during the session: How do we conduct an open and informed social discourse on the future use of AI? Who decides the ethical standards for the use of AI? How do we ensure not to hinder innovation but to keep pace with the evaluation of the potential use of AI? How is AI affecting the transformation of the job market, the digitalization of industrial structures, the education system, and the governance of social systems?

Prof. Subra Suresh began by highlighting three issues that affect the adoption of AI. The first

is the pace of change brought about by AI, which is more rapid than that of past industrial revolutions. The second is that individual citizens have the opportunity to have two-way real-time communication with the cutting-edge of technologies through mobile platforms. The third is unprecedented questions about whether humanity itself may be threatened by AI.

Prof. Suresh then presented six factors at the intersection of AI and society. The first is job creation versus job disruption, especially the time lag between the latter and the former. The second is the definition of an educated person. The third is the definition of what it means to be human. The fourth is whether humans can reverse AI questions, and do so in time before disasters happen. The fifth is how to prevent people from intentionally or unintentionally misusing AI. The sixth is whether human creativity will be affected by the push toward perfection and precision, catalyzed by technological progress.

Ms. Valérie Pisano shared three important points about AI in relation to society. First, there is global consensus that, if AI and society are to coexist, architecture and norms need to be created to ensure AI is used ethically. Through a multi-stakeholder dialogue, Montreal has issued the Montreal Declaration for Responsible Development of Artificial Intelligence. It lays out ten principles, including respect for people's autonomy, privacy, and the need for AI to be subjected to democratic scrutiny and control.

Second, AI may hold the key to tackling some of the most complex problems faced by society, such as access to education, improving health and living conditions, and climate change. For example, a group of researchers have set up an interactive website for regular citizens that shows an AI rendering of the impact of climate change on specific locations, in order to foster a sense of urgency for tackling this issue.

Third, AI will develop very quickly and become very fast at completing human tasks. This raises questions related to what it means to be human. It is necessary to recognize that humans themselves are imperfect. To ensure that AI is used for intelligent and positive purposes, it is essential to continue to invest in advancing human consciousness.

Dr. Yuichiro Anzai pointed out that AI is an information processing system that can discover new patterns from big data and can learn by itself. He also noted that AI is affecting society in profound ways, including job systems and industrial structures. These changes offer great opportunities for young people, in particular to work new jobs and develop new markets.

AI has positive and negative aspects. There are five key points to managing them. First, society should work together to enhance innovation by AI. Second, it is necessary to establish ethical principles around AI. Third, social systems and rules around AI are needed. Fourth, the international community must close the digital gap between developed and developing countries. Fifth, it is important to educate people to be able to distinguish between the positive and negative sides of AI.

Dr. Oren Etzioni noted that there are many social concerns around AI, including the risk that it will exacerbate existing biases, that it will eliminate jobs, or that it poses an existential threat to mankind.

In light of these concerns, it is necessary to clearly understand what exactly AI is. Dr. Etzioni made three points in this regard. First, it is important to understand the limited ability of AI currently. Second, one should not confuse intelligence with autonomy. Third, AI is a next-generation computer technology. It is certainly more sophisticated and

potentially powerful than past technologies, but it is still a technology or tool, and not a being.

Like all technologies, AI has the potential to be used for good or evil. Mankind has a shared responsibility to ensure the former. That said, AI must not be overly regulated, which would hinder its further development.

Prof. Ole Petter Ottersen spoke about the application of AI in the medical and healthcare sector. AI can outperform the human brain in some arenas, such as reading of medical imaging, so it is important to proactively introduce AI into society. However, the necessary preparations need to be made for society to safely accept AI. Otherwise, a wide range of ethical issues can occur.

Five ethical issues stand out. First, AI thrives on data, which raises the issue of respecting privacy and confidentiality. Second, patients must be empowered to have informed consent about the use of AI in their treatment or diagnosis. Third, the international community must ensure justice and equity, such that AI can be applied equally to different countries with different disease profiles and medical needs. Fourth, society must tackle the question of accountability for negative outcomes resulting from the use of AI. Fifth, it is necessary to distinguish between the use of data for the benefit of patients and their use for other purposes such as commercial ones.

Dr. Bernard S. Meyerson started by pointing out that the existential threats facing mankind, such as climate change, are of a scale that is far too vast for humans to handle. However, AI and machine learning can achieve this scale. A key question is how to ensure that these technologies are used ethically. Another problem is that it is increasingly difficult to maintain the anonymity of data.

Nevertheless, we must not lose the value of AI and machine learning because of the potential risks. Societies need to carefully consider each of the ethical questions that arises in relation to AI use. The right balance needs to be found, for example ensuring security without creating an Orwellian surveillance society. AI also has the potential to work as a "black box" and make completely opaque decisions. Taking an open-source approach to AI will ensure better transparency and put up guard rails for preventing AI from running off the tracks.

Q&A Session

Dr. Kleiner opened the Q&A session by wondering about the appropriateness of the name "artificial intelligence" and pointing out that no social scientists were involved in the naming process.

Dr. Meyerson did not like the name as it comes with a lot of baggage and because the word "artificial" implies "fake." He preferred the term "augmented intelligence."

Another audience member asked about the Montreal Declaration and its call for non-predatory use of AI.

Ms. Pisano believed that this issue can only be addressed through concerted efforts at the international level. She explained that the Montreal Declaration was aimed at framing some of the concerns to kick-start discussions.

The next question concerned how to deal with the minority of people who will not follow standards and norms for AI use.

Dr. Meyerson thought that it is inevitable that people will abuse technologies, but the first step is to establish rules about what is or is not acceptable.

Prof. Suresh believed that, the fact that some people will not follow the rule of law is not a reason not to create rules. It is also important to consider the social aspects of technologies, and for natural scientists and social scientists to work more closely together.

Dr. Anzai called for greater dialogue involving a wide range of stakeholders from around the world.

Dr. Etzioni believed that good progress is being made to set up standards and norms. Analysis of the various standards that exist shows that there is broad overlap and agreement among them.

Next, an audience member pointed out that AI is different and applied in different ways, depending on the industry, and asked if AI will change the way that industries should be regulated.

Dr. Etzioni said that regulation can be very blunt and slow-moving, and have unintended consequences. It is more useful to regulate AI application in a particular context, rather than regulate it as a general concept.

Prof. Ottersen commented on the regulation of AI in the medical sector, citing cases where algorithms create inequities. It is essential for society to think about how to ensure justice and equity.

Prof. Suresh pointed out that AI is capable of many new regulatory applications. The question is whether or not society wants AI to be applied in these ways. Such issues concern not only regulation but also democratic preferences.

Dr. Anzai believed it would be important to work out how to integrate ethics into software and how to distribute such software in the market.

A member of the audience believe that it would be impossible to keep digitally-recorded data private.

Dr. Etzioni pointed out that if people really cared about privacy, they could easily do something about it, but they would have to forgo some convenience.

Dr. Meyerson believed that society often makes the mistaken assumption that AI takes humans out of the equation. Humans are and will continue to be the guardrails for AI.

The last question concerned transparency and building open data sets.

Ms. Pisano said that her organization, as a principle, takes an open-source approach.

Dr. Etzioni believed that there are three levels of thinking about transparency that should be combined: transparency of input, which can sometimes be impractical; transparency of the algorithm itself, which can be too difficult to understand; and transparency of the outputs, which can be analyzed and audited.

Dr. Meyerson believed that humans have a responsibility to inculcate their values into AI systems.

Delivering Healthcare to the World

[Chair]

Roberts, Richard J., Chief Scientific Officer, Department of Genome Biology, New England Biolabs, U.S.A. [Nobel Laureate 1993 (Physiology or Medicine)]

[Speakers]

O'Kennedy, Richard, Vice President, Research, Development and Innovation, Qatar Foundation; Vice President, Research, Hamad Bin Khalifa University, Qatar

Suzuki, Yasuhiro, Vice-Minister for Health/Chief Medical & Global Health Officer, Ministry of Health, Labour and Welfare (MHLW), Japan

Suematsu, Makoto, President, Japan Agency for Medical Research and Development (AMED), Japan

Takasaki, Wataru, Corporate Officer and Head, R&D Division, Daiichi Sankyo Co. Ltd., Japan

Tumwesigye, Elioda, Minister, Ministry of Science, Technology and Innovation, Uganda

Opening Remarks

Sir Richard Roberts opened the session by noting that we often talk about improving health in developed countries, but it is also essential to examine how we can deliver better healthcare in the developing world. He stated that the session would focus on expanding genome sequencing from developed countries to developing countries, the role of microbes for good health, providing nutritious food for people around the world, dealing with the problems of aging and end-of-life issues in developed and developing countries, and collaboration between different nations.

Chair: Roberts, Richard J.

Dr. Richard O'Kennedy spoke about the genome and its role in better healthcare. All people are different and 'diseased' in their own unique ways. Using the genome information properly can ensure people live happier, healthier, and longer lives with better

quality-of-life. As drugs affect people differently, personalized medicine is important to deliver the right dose of a drug, to the right person at the right time.

We must also train individuals to handle and make best use of their genome information. We must also ensure that the enormous amount of data derived from the genome is used properly. Protection of data is vitally important, as well as engagement with people to allay their concerns about data protection. Engagement needs to take place in both developed and developing countries, to enable people to make informed decisions on their health or possible treatments. Dr. O'Kennedy highlighted the genome work being done in Qatar as an example of research outside western countries, with the collection of very extensive information on the 'Arab' genome.

Dr. Yasuhiro Suzuki raised three policy-related issues for delivering healthcare to the world: aging, the role of technology, and the importance of social cohesion. Dr. Suzuki highlighted Japan's view toward healthcare. Universal healthcare in the country was established well-before Japan's period of rapid economic growth based on the decision to make an investment in creating a healthy labor force. Now, Japan is seeing a population transition as young people increasingly pay premiums for the elderly while knowing their own payouts will not be as high when they are old.

Dr. Suzuki also raised the issue of wealth disparities, stressing that of the two possible responses of taxes or social security, social security is a far more powerful tool for income re-distribution. He emphasized that healthcare should not become something only the wealthy can afford, and that we are facing a danger of leaving the unhealthy behind.

Dr. Makoto Suematsu spoke about super-aging. It is predicted that by 2050, 18% of the world's population will be over 60 years old due to decreasing childbirth rates. However, Japan has become a super-aged society and only 35% of its population will be under 50 by 2040. Japan only has 20 years to find effective healthy longevity solutions. However, Dr. Suematsu stressed that there needs to be positive thinking, especially by focusing on the "silver market." He also noted the importance of appreciating human capital for elderly care.

Dr. Suematsu then discussed issues associated with global data linkage and sharing, including the General Data Protection Regulation in the European Union. He stressed that we need integration of siloed databases, but there are no such international initiatives now. There have been data-sharing initiatives in Japan, including linking the National

Database of Health Insurance Claims and Specific Health Checkups with the database on long-term care.

Dr. Wataru Takasaki also spoke about aging in Japan and the world. He stressed the importance of longer healthy life expectancy, rather than just a focus on living longer. He also highlighted the role of imaging technology in diagnosing dementia with MRI, AI, smartphone apps and IoT devices, and utilization of digital technology to provide more precise patient journeys.

Dr. Takasaki noted that research in the microbiome area is growing but still needs more development. Personalized and microbiome-based medical treatment will probably become the next trend. He also emphasized that patient-oriented drug discovery and manufacturing technology of drug modalities should not be siloed in order to promote drug development globally.

Dr. Tumwesigye Elioda began by noting that Uganda is beginning to conduct genomic research in its universities. Genomic research is important for improving detection and techniques handling diseases, as well as preventive actions. Genomic research can help people who are most affected by diseases and predict the efficacy of response. People with leukemia in Uganda now receive tests to see which medication they should use. Dr. Tumwesigye also noted his interest in the microbiome, including use of antibiotics early in life, medical analysis to understand the characteristics of the microbiome based on age, gender, and other factors, and information on the products that advertise microbiome benefits.

Uganda has many food-related challenges, and there is a major debate about how to feed its increasing population. One side argues for industrialized agriculture, pesticides, and GMOs, while the other side, often westerners, argues against this. Another problem is decreasing interest among young people in agriculture, but they are needed to populate the workforce and maintain Uganda's food supply and industry. In terms of aging, much of Africa's population is young and the elderly suffer due to lack of funds. Mr. Tumwesigye closed his remarks by emphasizing that Uganda welcomes international partnerships.

Discussion

Sir Richard began the discussion by asking for views regarding concerns from the general public about collecting human samples around the world.

Dr. O'Kennedy stated that there has been strong engagement with the population in Qatar for collecting samples. He stressed that people must be convinced of both the value and the security of their data. There needs to be a global examination of how to handle data, how to secure it, how to store it and about sharing it between countries, particularly for very rare diseases.

Dr. Suzuki said that the ease of collecting data depends on the person. It is easier to collect data from cancer patients because they are going to be tested anyway, but healthy people need to be convinced.

Dr. Suematsu stated that after the Great East Japan Earthquake, the Tohoku Medical Megabank established cohort studies to resolve medical problems in the aftermath of the disaster, including 200,000 healthy people.

Mr. Tumwesigye stated that in Uganda, if you explain the study truthfully to people, they willingly participate in research even if they are healthy. This was seen in Ebola and HIV studies.

Q&A Session

A member of the audience asked about economic feasibility of continuity of data.

Dr. O'Kennedy stated that it is important to model what Precision Medicine would yield in long-term health savings, as well as the benefits associated with better health and longevity.

Another member of the audience asked about how to handle the issue of increasingly severe mental issues around the world.

Sir Richard noted that the microbiome communicates with the brain, although much more research needs to be conducted on this.

Dr. Suematsu agreed with Sir Richard. Food is nutrition not only for the human being but also for microbes. He also called for more basic research in this field, especially as most pharmaceutical companies have not been able to develop a pill for neuropsychiatry and regenerative diseases such as dementia.

A member of the audience asked about willingness to give samples, noting that most people in Finland provide them. The Finnish government has built up the legal architecture around data in a transparent way, and has also undertaken initiatives such as anonymizing data when companies use it.

Sir Richard agreed that Finland is a country where people trust the government, noting that the same is true of the United Kingdom. However, privacy is of the utmost concern in countries such as the United States.

Dr. Suematsu noted regarding privacy that the situation is completely different in the United Kingdom than Japan. The NHS clearly states on its website that secondary use of data could be by companies. He stressed that this needs to happen in Japan through reform.

The final questions were on Japan's extremely low replacement rate and the possibility that this problem could be much more severe than predicted, as well as on the phenomenon of people returning home to care for their elderly parents.

Dr. Suzuki answered that Japan has a strong phenomenon of older people working past 65 compared to other countries, meaning that the elderly can continue to contribute to social security and society.

Basic Science, Innovation and Policy

[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]

Yonath, Ada E., Director of The Helen and Milton A. Kimmelman Center for Biomolecular Structure and Assembly, and The Martin S. and Helen Kimmel Professor of Structural Biology, Faculty of Chemistry, Weizmann Institute of Science, Israel [Nobel Laureate 2009 (Chemistry)]

Honjo, Tasuku, Distinguished Professor, Institute for Advanced Study, Kyoto University, Japan [Nobel Laureate 2018 (Physiology or Medicine)]

Tan, Eng Chye, President, National University of Singapore (NUS), Singapore

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

Hielscher, Christoph, Managing Director Siemens Technology & Innovation Council (STIC), Siemens AG, Corporate Strategy, Siemens, Germany

Chair: Gruss, Peter

Opening Remarks

Dr. Peter Gruss opened the session by speaking about the rapid shift in technology exemplified by technologies such as AI and advanced robotics, which he noted would challenge definitions of what it means to be human. We will always require innovation, and new technologies will bring new challenges. Providing strong support to basic science and fostering the next generation will become increasingly important to adequately prepare mankind for the future. The greatest challenges facing humanity can only be solved through interdisciplinary efforts.

Dr. Ada Yonath presented her experience working in the field of basic science. Her initial interest in understanding the basic building blocks of life at molecular level eventually led to new and unexpected discoveries – for example the development of new and novel ways to make antibiotics. Curiosity driven approaches in basic science research have resulted in many other instances of experimental procedures helping mankind. It is important to pursue one's own curiosity in order to make a real impact on scientific research.

Dr. Tasuku Honjo began by stating that biology or life science was a relatively young field of research given the relative lack of theory and clear principles. Innovation is the creation of new value by combination of different knowledge seeds – but the critical point is how to create seed discovery. New discovery requires patience and time, and the elder generation must encourage young researchers to feed their curiosity. However, to enable these environments the support of government and society at large is required.

Dr. Eng Chye Tan claimed that basic research and government support for basic research are crucial. He discussed the research-innovation-enterprise ecosystem, and the cultivation of talents for the ecosystem. He is unsure of the ratio or proportion of total funding that should go to basic research, as different countries have developed different environments, challenges, capabilities, strengths and weaknesses.

Industry, government, and academia are the three important stakeholders in this approach. Singapore provides one example of such a scheme where corporate laboratories exist to help bridge the gap with private industry. Spin-offs and startups should also be supported as part of the innovation ecosystem.

Dr. Jean-Pierre Bourguignon began by speaking about the importance of understanding the triangle between science, innovation, and policy. The industrial ecosystem must change drastically because of the challenges we face globally. Even so, new solutions may take some time to appear. For example, AI began in the 60s and 70s, and was driven by logical and mathematical approaches. Later on, its progress slowed, and a critical level of development was only reinvigorated when AI, nurtured by big data, adopted another paradigm and had a decisive growth. This shows that fresh approaches can open new doors.

Dr. Bourguignon noted that stimulating researchers early in their careers was also important. The structure of academic life may hinder such a stimulation. Given that major discoveries tend to happen at the boundaries of what is known, a right ecosystem and environment for

colleagues, in particular young researchers, are required if one wants them to change the world. Finally, governments must accept the idea that the only way to contribute to change is to take a long-term view, instead of a shorter one driven by election cycles. To resist short term outcomes, to stimulate researchers, and to convince policymakers that the only way out is the long-term view.

Mr. Christoph Hielscher discussed the role of large companies in innovation ecosystems. He first noted that they face certain restrictions. If you look at breakthroughs like e-commerce or molecular diagnostics, you will see that they were driven by start up companies and not large industries.

Mr. Hielscher continued, stating that profit margin expectations and increases in pressure of disruptions limit the freedom of incumbent and traditional companies. Statistically 1 startup out of 10 is successful, and therefore adopting the same approaches in a traditional company is difficult. For traditional companies, the key focus in on sustaining innovation, from incremental to radical and digital enhancement. Good examples are new materials, AI, e.g. for predictive maintenance and new business models. However, only sustaining innovations would eventually devaluate the company.

Active portfolio management and understanding which markets you should stay, leave or focus on is essential. Traditional methods for strategy planning are not sufficient, and large data and various other approaches such as scenario development with external input are required, especially to access disruptions correctly. Collaboration with startups at various

levels, from early to late stage is very important for large companies, including the investment into these. Acquisitions are also of great importance.

Discussion

Dr. Gruss asked the panel to share their early career experiences working on basic research, and comments on the current issues facing the world in terms of funding and raising the next generation of leaders in science.

Dr. Yonath reiterated her strong belief that pursuing questions and topics that individuals are curious about, and taking non-traditional approaches to research, worked well based on her own experience.

Dr. Honjo answered that he had been fortunate in the timing of his career as both molecular biology and the Japanese economy started to grow when he entered the work force. For the future generations, one issue is the increasing cost of research not being met with increased research funds provided by the government. Since the future of life science has enormous potential, governments and academia must promote and support it.

Dr. Bourguignon commented about the importance of placing trust in individual scientists, describing some of the mechanisms available to European Research Council researchers including a Proof-of-Concept programme to help research contribute to societal and market needs. Many scientists practicing basic science are interested in translating their research into real world applications, and we must be supportive in nurturing that potential.

Dr. Tan commented that many mechanisms to support basic research exist in Singapore. Professors can be good at generating ideas, but to translate those into commercial opportunities can be difficult. We select post-docs and PhD students who show entrepreneurial promise and bring in venture capitalists to match promising ideas with industry backers. Such programmes to deliberately capitalize on ecosystems are essential.

Dr. Gruss then asked about the internal resistance to risk within large companies, and how companies can create innovation despite this cautious approach.

Mr. Hielscher answered that cooperation with academia was essential as was proof-of-concept delivery to industry. More radical business models and ideas engage from early seed to late stage by offering financial benefits and access to sales channels, R&D, etc., which is the vehicle for this purpose.

Dr. Gruss then asked whether or not companies are a chance or threat for basic research.

Dr. Bourguignon noted the current job market, commenting that many young individuals faced higher hurdles and less likelihood of obtaining ideal employment compared to past generations. We need to enable and empower young researchers to lead projects, which will allow them to think independently, and recognize the long-term benefits they will obtain from sticking to basic science research long enough.

Q&A Session

- A member of the audience asked about the transition of funding from basic research to applied research for innovation purposes.

- Dr. Honjo answered that there were substantial opportunities to create value for both forms of research, but that basic research could have a longer timeline. Therefore, we must maintain support for basic science even if profits are not created in the short term, as history has proven this time and again.

- Dr. Bourguignon noted that many recent examples show that innovations nurtured by basic research may occur rapidly. There are lot of feedback mechanisms and cross-functional schemes that combine elements of both applied and basic research.

- Another audience member asked about the evaluation criteria of researchers in terms of nurturing curiosity, and the separation of applied and fundamental research in terms of timelines.

- Dr. Tan noted that in Singapore, a system of evaluation drawing from best practices globally was in place.

- Dr. Honjo spoke about his belief that the scientific community should collectively decide who gets funding, and not leave the decision up to government.

Development and Sustainability for the Future of Humankind

[Chair]

Holt, Jr., Rush D., Chief Executive Officer Emeritus, American Association for the Advancement of Science (AAAS); former Member of U.S. House of Representatives (1999-2015), U.S.A.

[Speakers]

Schmidt, Brian P., Vice-Chancellor, The Australian National University, Australia [Nobel Laureate 2011 (Physics)]

Strohschneider, Peter, President, German Research Foundation (DFG), Germany

Omi, Koji, Founder and Chairman, Science and Technology in Society *forum* (STS *forum*); former Minister of Finance, Japan

Opening Remarks

Dr. Rush D. Holt, Jr. opened by stating that, for 16 years, STS *forum* has been a venue for civil and collegial discussion, for the celebration of the lights of science and technology, and for honestly confronting the real problems that come from and can be partially addressed by science and technology.

Chair: Holt, Jr., Rush D.

He then shared his thoughts on sustainability. The climate and environment are becoming ever more unstable due to human activity. This situation is not sustainable. Sustainability is a higher bar than many might think. It requires not only halting degradation or restoring the degraded parameters, but to ensure continued resilience against future degradation. We must think at least hundreds of years into the future. Sustainability will require drastic action. Moreover, time is of the essence. In addition, we must close the growing gaps in society, which are inherently unsustainable. To do so, we must address the needs of developing countries and local communities.

STS *forum* has affected the international dialogue on sustainability. Nevertheless, there is so much further to go. We cannot justify the lack of progress by blaming others. If we fail, we all fail.

Prof. Brian P. Schmidt believed that humanity must fight to live sustainably on our small planet. The greatest threat to sustainability is human-driven climate change. Little progress has been made to tackle this issue since the Paris Agreement, which set out already weak targets. The global citizenry is seeing a critical failure of the global political system.

Yet, there is reason for hope. We have technological solutions that can help. However, time is not our side. We need track-1.5 and track-2 processes to accelerate efforts to address climate change. It will also not be possible to tackle climate change at the necessary speed and scale without a global price on carbon. Such a price must be set by a coalition of the willing.

To slow population growth, we need higher-quality education and to increase the income of the world's most impoverished people. The provision of better education at lower cost to developing countries is essential. There is no reason not to act.

In addition, digital economic systems that disintermediate governments are also very useful and are more inclusive than traditional systems. Disintermediated governments may be frightening for developed countries, but represent a huge opportunity in countries where governments are not able to provide a platform for economic growth.

There is also great economic value in missions or modern moonshots. Saving the planet does not need to cost the economy. We need moonshots to secure the future of humanity. Through a coalition of the willing, comprising businesses, institutions and nations, we must take action to limit greenhouse gas emissions and global population growth. There is no time to wait.

Prof. Peter Strohschneider pointed out that sustainability connects the grand challenges faced by mankind. The principle of sustainability is itself a topic of research because it is linked to a wide range of research topics. All of these research topics must be supported and funded. It is clear that research should contribute to the achievement of sustainability goals. However, the crucial question is how best to achieve this.

Prof. Strohschneider presented four theses on how research could contribute to sustainability goals. First, the discourse on grand challenges presents the problems of global change in

Schmidt, Brian P.

Strohschneider, Peter

a way that give the false impression that they are manageable basically, if not exclusively, by science and technology. Grand challenges are a structural concept which needs to be broken down into smaller and more manageable research topics of equal value, for which the criterion “contributing to tackling a grand challenge” is not particularly useful. Second, sustainability can only be achieved through pluralistic research systems, that value and fund both utility-oriented and curiosity-driven research. Third, we must do away with research policy positions that reduce sustainability to a simple test criterion that becomes generalized as a principle of research organization and funding. Lastly, it is a mistake to frame research merely in terms of their direct usefulness for achieving the SDGs, as it establishes a false opposition of “truth” and “utility,” as if untrue knowledge were useful, or the quest for truth could be programmatically useless.

Mr. Koji Omi provided the closing remarks by summarizing the key conclusions of the 16th Annual Meeting of the STS *forum*. Climate mitigation is essential for future sustainable development. The right energy policies can manage energy supply and demand more effectively. Nuclear energy should remain an essential carbon-free option, under the strict conditions of safety, security and non-proliferation.

In the area of life sciences, healthy aging is a key issue for society, while microbiome research can contribute to future health management.

AI possesses great potential for improving society and tackling the challenges we face. However, issues of privacy and security must be adequately managed.

Sustainability must remain the prime concern of the international community. International collaboration is essential. More open exchanges are also required. In addition, it is necessary to nurture the leaders of the future and encourage broader participation of women, as STS *forum* is doing.

Omi, Koji

STS *forum* has grown from a mere conference to a global movement where leaders from government, academia and industry meet to engage in meaningful dialogue on the major issues faced by society. We must continue to strengthen the lights and dampen the shadows of science and technology, and work together to pave the way for future generations.

Concurrent Sessions

Key Messages from Concurrent Sessions

[Chair]

Kumar, Ashwani, Senior Advocate Supreme Court; former Union Minister of Law & Justice; former Member of Parliament (Rajya Sabha), Supreme Court of India, India

[Speakers]

Schoonen, Martin, Associate Laboratory Director, Brookhaven National Laboratory, U.S.A.

Duszyński, Jerzy, President, Polish Academy of Sciences (PAS), Poland

Kajiwara, Yumiko, Executive Member of the Council for Science, Technology and Innovation, Cabinet Office (CAO), Japan

Falk, Jim, Honorary Professorial Fellow, Melbourne Sustainable Society Institute, University of Melbourne; Emeritus Professor, The University of Wollongong, Australia

Hassan, Mohamed Hag Ali, President, The World Academy of Sciences (TWAS), Italy; President, Sudanese National Academy of Sciences (SNAS), Sudan

Pacheco, Carlos Américo, CEO, State of São Paulo Research Foundation (FAPESP); Professor, Institute of Economics, State University of Campinas (UNICAMP), Brazil

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

Sulaiman, Mohd Yusoff, President & Chief Executive Officer, Malaysian Industry-Government Group for High Technology (MIGHT); President, Malaysia Rail Industry Corporation (MARIC), Malaysia

Bercovici, Moran, Associate Professor, Mechanical Engineering, Technion - Israel Institute of Technology, Israel [Young Leader 2019]

Lee-Waddell, Karen Li Guen, Postdoctoral research scientist, Astronomy and Space Science, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia [Young Leader 2019]

Chair: Kumar, Ashwani

Opening Remarks

Dr. Ashwani Kumar explained that the purpose of the session is to report on the key messages from the 24 concurrent sessions, which dealt with the various ways and means to make the world a better and happier place. He then shared the lesson that the past melds itself into the present, while the present projects itself into the future, highlighting how the actions of today will shape the future for the coming generations. It is commendable that STS *forum* recognizes this fact, and seeks to change the future for the better through science and technology.

Schoonen, Martin

Science and technology, as well as innovation, will provide the answers for the challenges of the future. However, they need to be directed in a framework that recognizes and mitigates the contradictions and frailties of humankind, as it is a real risk that they may be abused. It is mankind's right and indeed responsibility to uphold its own moral dignity.

It is interesting to note that although society enjoys the greatest abundant material prosperity in history, in many ways society is also very impoverished, for example in terms of discrimination, violence and inequities. Human dignity is the key to understanding and realizing the benefits of science and technology. It is necessary to discuss not only the lights of science and technology, but also the shadows. It would be a mistake to allow ourselves, in our exuberance, to ignore them.

Dr. Martin Schoonen presented the key messages from the energy track. There is a clear need to transition to a low-carbon and eventually a zero-carbon society. It is also necessary to address energy poverty around the world, taking into account local issues and needs.

There is no one solution to achieve carbon neutrality, but any solutions should allow for economic growth while reducing emissions. Some industries will face bigger challenges than others and will require fit-for-purpose solutions. There are already a number examples of governments implementing economic and feasible energy solutions in remote areas facing high fossil fuel cost or a lack of energy infrastructure.

Society should develop roadmaps towards achieving carbon neutrality that are underpinned by all available technologies. Urban centers can develop strategies for reducing energy consumption, such as energy-efficient buildings. Meanwhile, solving energy problems in

Duszyński, Jerzy

rural areas will create economic opportunities, which may affect the trend of migration to cities.

By bringing together members of industry, policymakers, and scientists from a wide range of field, STS *forum* is the ideal place for shaping the future.

Prof. Jerzy Duszyński summarized the discussions from the life sciences concurrent sessions, which concerned three emerging areas of study that are growing in importance. First was healthy aging. This is a complex issue but there is consensus that lifestyle is a major factor. Exercise, social interaction and diet are important in ensuring healthy aging. As healthy aging is a major issue for societies and economies, large-scale programs have been initiated to deal with it. Prevention is essential and good habits should be taught and implemented early in life. Another key issue is preventive drugs. More studies need to be done to prove their efficacy. New technologies will help tackle issues related to aging.

Another key topic was the microbiome, the complexity of which is becoming ever more evident. New technologies allow more advanced analysis of the microbiome and its relation to diseases. However, this will generate huge amounts of data that can only be properly analyzed with the appropriate expertise. The microbiome is very sensitive to people's lifestyles and changes in the environment, making it very difficult to understand. Further basic studies of the microbiome are needed as it is a field of immense importance.

Precision medicine was also discussed. Precision medicine is very dependent on individual background and new technologies. The field is in its infancy but it is rapidly developing.

Ms. Yumiko Kajiwara highlighted the key messages from the engineering and innovation session. Technology and innovation have been advancing and implemented in society. Nevertheless, government, academia and industry must continue to collaborate for

sustainable solutions for society. Both mission-driven and curiosity-driven research have parts to play.

Industrial innovation plays a critical role in improving lives and making society sustainable. More efforts are needed to bridge the gap between industry and academia. This is an area where policymakers can help, with incentives, regulations, or measures such as social consortia.

Kajiwara, Yumiko

New engineering technologies were also discussed. There are must-have technologies, where clear missions are required for leading promising ideas into reality, and also like-to-have technologies, such as quantum technologies, which are often driven by the curiosity and creativity of young researchers. Having the right balance between mission-driven and curiosity-driven research is important. Push and pull factors such as interfaces with society can help. The right incentives and regulations are also important.

The third session was on robotics. Robots need to be more symmetric to humans as robotics further continue to amplify or augment human activities. They are not a threat to human jobs. Higher education will need to evolve to foster human resources that can properly operate these robotics. It is also necessary to certify the safety of robotics, which will require the engagement of insurance companies. Furthermore, the supply of energy robots and data centers needs to be considered. In addition, disassembly needs to be included in their design. Ethics also need to be considered when utilizing new technologies including AI. Continued discussions on these topics through multi-stakeholder dialogues such as STS *forum* will be highly valuable.

Prof. Jim Falk provided a summary of the dialogue from the environment track. One of the key messages was the emerging threat and impact of climate change. Much constructive activity has been devoted to addressing this issue over the past decades, in terms of dialogue, international agreements, technological innovation, and so on. Unfortunately,

Falk, Jim

these lights are overshadowed by the challenges. The human population continues to grow, and with it resource and energy needs. Despite great progress in renewables, renewable and nuclear energy still account for a small percentage of total power generation sources. Accumulation of CO_2 in the atmosphere continues to grow at a high rate. To reverse this trend, massive transformation is needed across the globe, both in developed and developing countries.

Another key message was the consensus that whilst society knows what needs to be done and the right technologies largely exist, sufficient political will is lacking. That needs to be built from the ground up requiring serious engagement with local communities at local scale. Only in this way can the necessary political will be built. This will require better scientific communication and better efforts to tackle local issues.

In addition, Prof. Falk presented a summary of the Regional Action on Climate Change (RACC) Meeting held before the opening of the Annual STS *Forum*. The Meeting noted that, in relation to climate change, the global situation has dramatically worsened in the past decade. Scientific bodies continue to demonstrate the irrefutable scientific basis of human impact on the climate, yet greenhouse gases continue to accumulate in the atmosphere. Effective adaptation and mitigation actions at a global scale are needed urgently. The issue is not a lack of understanding of the necessary actions and technological solutions, but a lack of leadership, political will and finances being made available where they are needed. Initiatives to engage local communities and generate regional actions are vital. These initiatives need support from central governments. Only in this way can we generate momentum to make the necessary social and political transitions to adapt to and mitigate climate change.

Prof. Mohamed Hag Ali Hassan shared the key messages from the concurrent sessions on cooperation in science and technology. There were two common and interrelated

Hassan, Mohamed Hag Ali

issues addressed in the sessions: the role of cooperation in science, technology and innovation between different countries to accelerate efforts to achieve the Sustainable Development Goals (SDGs), as well as the role of rapidly advancing technologies for achieving the SDGs. Government-industry-academia cooperation will lead the way to the successful application of technologies for the achievement of the SDGs.

One of the key messages to emerge is that there has been a dramatic change in the science and technology landscape in developing countries. The Global South is making increasingly large contributions to global science and technology. This creates new opportunities for innovation and for science diplomacy. Nevertheless, several low-income and lower-middle income African countries are lagging behind in the development and application of science, technology and innovation for the benefit of their societies. There is a need to promote STEM education in these countries, something that the Japanese government has been working on in collaboration with the higher education institutions in Africa and Japanese universities. Another issue is the migration of qualified scientists from developing countries to developed countries. Scientific exchange programs involving diaspora scientists can be of great benefit to build and maintain the science and technology capacity of developing countries.

Another key issue was the use of science as a tool to build or strengthen relationships between countries. Scientists need to and are increasingly collaborating with others in their field, across national borders. There are many excellent examples of international scientific collaboration and diplomacy, such as the International Space Station. Scientific diplomacy is also growing in popularity among the younger generation.

In addition, Industry 4.0, driven by digital technologies, offers great opportunity for government-industry-academia cooperation towards the achievement of the SDGs. To capitalize on this, new forms of education are needed. Furthermore, all governments should support

Pacheco, Carlos Américo

collaboration between academia and industry. One way is to provide joint research grants for specific problems related to the SDGs. In addition, research and technology organizations have a role to play in bridging the gap between government, industry and academia. Furthermore, academia operates at a much slower timeframe than industry. Governments must provide funding for basic research and encourage industry to support and collaborate with academia.

Dr. Carlos Américo Pacheco presented the messages from the track on science and technology and society. One of the main topics was the role of research in addressing the issues of society. However, society must be aware of past shortcomings of the application of science. In a polarized environment, every effort needs to be made to restore trust in science. Research collaboration with industry and multi-stakeholder dialogues are needed to promote efforts to achieve the SDGs and prevent the misuse of technology. They must also ensure that technologies are implemented in a way that benefits all of society. Capacity building in relation to scientific communication is also required.

Another subject was innovation ecosystems, which enable a diverse range of stakeholders to use innovation to contribute to society. Digitalization has made the world increasingly borderless and deeply impact innovation ecosystems. To move forward, we must recognize and address the existing shortcomings of innovation ecosystems. We must provide the necessary environment and funding, including being accepting of failure. Innovation is about the future and we must therefore encourage the next generation to become entrepreneurs and take risks. Additionally, models differ by institution and each institution must develop its own model. This also makes it difficult to design policies for innovation. Policymakers should focus on goals, rather than being overly prescriptive.

There was also a session on information and communication in the digitalized society. In the session, it was pointed out there has been an increase in the use of the web for fraud

and other illicit purposes. Furthermore, while social media can connect people across borders, they can also be used to spread misinformation. It is difficult but essential that we maintain trust in the Internet. One way to do this is to improve digital literacy from an early age. The scientific community also needs to engage with society to ensure that science is a tool for spreading truth and not for reinforcing existing prejudices. In addition, cybersecurity in communications needs to be improved. For this, a sense of personal responsibility must be fostered.

Kitano, Hiroaki

Dr. Hiroaki Kitano summarized the key points from the ICT concurrent sessions. A central subject was trust and trustworthiness. ICT is one of the key tools for achieving the SDGs and promoting diversity. Indeed, there is much evidence of ICT doing just that.

However, these efforts rely on sensors that generate huge amounts of data, which bring with them concerns about privacy and security. The level of complexity in the government and industrial sectors are different, which in turn lends more complexity to issues of informed consent and privacy.

In addition, there are increasing cases of ever more sophisticated cyberattacks. Cyberattacks target the weakest links in security systems, which are usually individuals. The awareness of each individual, as well as potential systemized ways of dealing with this vulnerability, are vital.

Another subject was AI. AI has great potential to enhance what humans and society are capable of. However, it can also reflect bias in the data source. We must ensure that AI is fair, accountable and transparent. For that, we need to change the mindset of society and also set up systems for detecting potential biases. Research and deployment towards trustworthy and transparent AI systems is of the utmost importance.

Sulaiman, Mohd Yusoff

The aforementioned issues are well known and have been widely discussed. STS *forum* is a very important venue for spreading awareness of these issues, and generating actual actions for tackling them and mitigating the relevant risks.

Dr. Mohd Yusoff Sulaiman provided a recap of the discussions from the concurrent sessions on social infrastructure. The first topic was advanced transportation. The key consideration was how to make mobility more efficient, convenient and inexpensive, as mobility is key to making cities smarter.

Another subject was agriculture. One of the key issues raised in relation to this was deforestation and the need for more careful policies in the future.

Another key message from the sessions was that while science, technology and innovation have great potential to improve society and tackle social issues, there are also many potential unintended consequences that are often overlooked.

In addition, while society often understands the why and what of many issues, the lingering question is how to tackle these issues. This is particularly true for developing countries. They need the collaboration of developed countries, who can share their experiences and insights.

Report by the Young Leaders

Prof. Moran Bercovici spoke about his impressions from attending STS *forum*. One of the key messages he noted is the continued importance of curiosity-driven research. This furthers our understanding of nature and may yield potential applications in the future.

In addition, climate change was one of the key themes of this year's meeting. It is clear that mankind must take urgent action, for which more political will is needed. In preparation for that, government, industry and academia must continue to develop all possible technologies that could contribute to tackling this issue. As part of that, funding for basic research remains very important.

Dr. Karen Li Guen Lee-Waddell spoke about her experience attending STS *forum*. The meeting has been inspirational and is a testament to how people can and should work together to deal with the huge issues facing society. These issues require the combination of the skills and minds of people around the world. Real collaborative research across different industries and real collaborative action are essential.

Bercovici, Moran

Dr. Lee-Waddell also valued the opportunity to meet and interact with Nobel laureates. One of her key takeaways from the meeting was the importance of continuing to be inquisitive and trusting one's research.

Lastly, she highlighted the value of the discussions that have taken place at STS *forum*, while calling on the participants to now take action.

Lee-Waddell, Karen Li Guen

Closing Remarks

In closing, Dr. Kumar once again highlighted the powerful potential of science and technology for good, but also the risks that come with them. That STS *forum* and other organizations continue to debate the same issues is a testament to the fact that these issues are not trivial. Nevertheless, we must continue to hold these dialogues, take action, and have confidence that the solutions are not beyond human ingenuity.

Energy
Renewable Energy and Management Systems

[Chair]

Nathwani, Jatin, Founding Executive Director of Waterloo Institute for Sustainable Energy (WISE), and Professor and Ontario Research Chair in Public Policy for Sustainable Energy, University of Waterloo, Canada

[Speakers]

Ishizuka, Hiroaki, Chairman, New Energy and Industrial Technology Development Organization (NEDO), Japan

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

Morin, Gregory S., Director for Strategy and Risk, Office of the Director, Argonne National Laboratory, U.S.A.

Eamchotchawalit, Chutima, Governor, Thailand Institute of Scientific and Technological Research (TISTR), Thailand

Gielen, Dolf, Director, IRENA Innovation and Technology Centre, International Renewable Energy Agency (IRENA); Germany

Houssin, Didier, Chairman and CEO, IFP Energies nouvelles (IFPEN), France

Wong, Albert, Chief Executive Officer, Hong Kong Science and Technology Parks Corporation, Hong Kong

Opening Remarks

The chair opened the session by stating that it would examine the challenges of climate change and universal energy access, requiring radical scientific and social innovation. To ensure a cost-effective transition to a low-carbon energy economy, critical factors include a creative approach to new distributed energy technologies, energy storage and battery technology advances, SMEs and entrepreneurs, digitalization and smart energy networks, and the role of electrification including hydrogen.

The speakers then discussed Japan's New Energy and Industrial Technology Development Organization (NEDO), which tackles addressing energy and global environmental problems and enhancing industrial technology. It focuses on developing sustainable energy resources, investment in countering climate change, realizing large-scale renewable energy integration, and more. NEDO particularly emphasizes international cooperation and the necessity of radical innovation through international joint R&D initiatives.

The discussion then turned to the fact that installing renewable energy itself will not be enough. There needs to be a transition of the whole system, including addressing the inertia in renewable energy. Temporal and spatial issues must be tackled to bring renewable energy into the grid, which was not originally designed for renewable energy.

There was then a discussion on how to make "the old new again," such as Argonne National Laboratory's work to improve lead-acid batteries, an old technology that is still popular worldwide. To manage the high failure rate of entrepreneurial renewable-focused ventures, the Lab-Embedded Entrepreneurship Programs enable performing early stage R&D with many facilities and benefits.

Following this, there was an introduction of the Sustainable Development Group in Thailand. Green energy from renewable sources is the key to cope with the climate crisis. Innovation in technology and business models needs to be accelerated, such as blockchain energy management systems and peer-to-peer energy trading.

Next, it was pointed out that there has been clear progress in renewables, including Germany's success in achieving a 47% renewables share. While technology is important, so too are market design, operation practices, and business models. Green hydrogen is also seeing much progress, as discussed at the recent Hydrogen Energy Ministerial Meeting in Tokyo.

Chair: Nathwani, Jatin

It was then noted that costs are much lower now for solar and wind power, making renewables increasingly competitive in many countries. However, governments must maintain incentive frameworks to promote investment in renewables and accessibility to power systems. The digitalization revolution will provide badly-needed enhancement of energy system management.

Finally, it was noted that although the capital cost of building a renewable power plant is

much higher than fossil fuels, the lifetime cost for renewables is actually cheaper. Although technology is important, it is also vital to consider innovation of business models and financing to help push past the high initial costs to reap the lifetime cost benefit presented by renewables.

Discussion

Following the opening remarks, a group discussion was held. One discussion flowed from energy poverty to efficiency of energy systems, controlling costs while consuming more, and the role of education systems and raising taxes to make people understand the importance of reducing consumption.

The cost of Germany's success in achieving 47% renewables was also examined. It was noted that we should aim for the top at 100% renewables to bring up the eventual percentage. Energy storage is becoming cheaper, which will be crucial for large data centers. New generation batteries are competitive with hydrogen, and are using fewer rare materials.

The diversity of the participants yielded discussions that covered many different countries, including success in renewables in Australia, Japan's net-zero energy building target,

Kuwait's desalination through renewable energy that can eventually produce hydrogen, and Thailand's biomass applications for transportation.

It was also noted that most energy is needed for heating and cooling, so politicians should give incentives for optimal use of electricity. It will also be important to use fossil fuels better, as they will continue to be used in the short-term future.

Another topic was innovation, SMEs, and disruptive distributed energy technologies. Beneficial regulation is needed as well as market creation for digitalization and the smart energy approach, incentivizing investment and overcoming the barrier of early costs for new technologies. The discussion also encompassed mitigating climate change such as Carbon Capture, Utilization, and Storage (CCUS), with the note that more investment is needed to develop such technologies.

It was finally stressed that we should be positive when tackling climate change, as electrification is a pathway to both GPD growth and decarbonization goals. The major theme of the session was that not only technology, but also regulation, market expansion, the role of SMEs and entrepreneurs, and social innovation are all key factors for tackling energy challenges.

Energy
Action for Net-Zero Emissions

[Chair]

Abdul Hamid, Zakri, Chairman, Atri Advisory; former Science Advisor to the Prime Minister of Malaysia, Malaysia

[Speakers]

Godrej, Nadir B., Managing Director, Godrej Industries Limited; Chairman, Godrej Agrovet Ltd, India

Grånäs, Oscar, Staff Scientist, Physics and Astronomy, Uppsala University, Sweden [Future Leader 2018]

Hüttl, Reinhard F., Vice President, National Academy of Science and Engineering (acatech), Germany

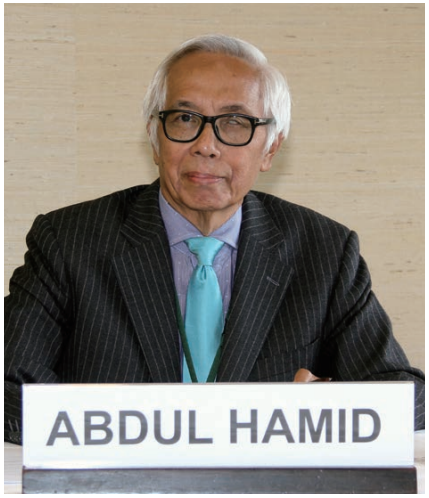
Isaacs, Eric D., President, Carnegie Institution for Science, U.S.A.

Nakicenovic, Nebojsa, former Deputy Director General and CEO, International Institute for Applied Systems Analysis (IIASA), Austria

Nishimura, Motohiko, Vice Executive Officer, Hydrogen Project Development Center, Kawasaki Heavy Industries, Ltd., Japan

Penfornis, Erwin, Vice President, Hydrogen Energy, Asia Pacific, Air Liquide

Opening Remarks



Chair: Abdul Hamid, Zakri

The chair began the session by stating that emissions efforts are not keeping up with our energy consumption. A net-zero emissions future must include primary energy shifts from high carbon to low carbon, and then to renewable energy, energy storage, and eventually electrification of the economy.

Next, there was insight on climate change, net-zero emissions, and innovation. The weather has a wider range, but some outliers deny climate change. It should be clear for all to see that energy presents the key. While wind and solar are both clean, challenges are clearly seen. Technology and innovation

can pave the way to put these challenges at bay.

Next the speakers cited the IPCC report stating that mankind has the technology needed to mitigate climate change. Unfortunately, politicians and others often prioritize short-term growth over climate change response, but it is possible for many countries to increase their GDPs without increasing their carbon footprint. Ultimately, the focus needs to shift to QOL. Sweden is striving to be a model for sustaining a public welfare system with net-zero emissions.

The discussion then turned to the transition to renewables in Germany, including the complete elimination of nuclear power. A systematic approach is being taken, achieved through targets for the energy mix and subsidies. Presently renewables make up 15% of all sectors of the energy supply with a majority being biomass. CO_2 emissions have not significantly decreased because of the elimination of nuclear power, so Germany has decided to also abandon coal completely by 2038 at the latest.

Another topic was carbons that present difficulties for net-zero emissions. The three categories are transportation-related, production of carbon-intensive structural materials, and reliable load following energy. They constitute a major percentage of CO_2 emissions. Challenges include that transportation alternatives require more volume and displace cargo, as well as varying electricity demand. The biggest issue will be scaling alternative carbon-free fuels and materials.

The next point was that climate change should be approached with a holistic perspective, such as the SDGs. Although accurate predictions regarding climate change were made decades ago, little has been done despite the fact that we know what we need to do. It is necessary to transform the entire energy system, including carbon-free energy sources, a combination of hydrogen and electricity as energy carriers, carbon-free end use such as vehicles, buildings and industry, as well as efficiency improvement.

The discussion then turned to hydrogen as a solution for a net-zero society. It can be utilized to achieve decarbonization in diverse sectors such as mobility, power, heating etc. A broad spectrum of players would be needed to achieve a hydrogen society, which may contribute to the economy and employment, as well as emission reduction. Kawasaki Heavy Industries is developing hydrogen gas turbine combustion technology and other related hydrogen initiatives and pilot projects.

Additional insight about hydrogen included the point that it could be the perfect solution to the issue of “hard-to-abate” CO_2. Hydrogen is essential for integration of renewables, mobility electrification, and recycling industry CO_2. Hydrogen development is dramatically accelerating and is now fully ready for scale-up. However, frustrations include the need for more ambitious emission reduction targets to be set by Governments across sectors and that we are falling short due to a lack of political measures.

Discussion

Following the opening remarks, a group discussion was held. It was noted that for net-zero emissions, scalability is the key. Although we have a scientific understanding of low carbon solutions such as hydrogen, we do not know how to achieve them economically. Scale is an engineering problem, and it will be helpful to learn by experience through new engineering initiatives.

Another conversation centered on accelerating transformation, including the question of top-down versus bottom-up approaches. A top-down example would be a United Nations roadmap, but some argue that change should be driven by local decision-makers. There is also focus on people from wealthy countries consuming less, driven by the enthusiasm of the young generation.

Hydrogen was also discussed. By 2030, hydrogen use in industry should be possible through scaling up and developing the value chain with governmental support. Japan is leading in supporting hydrogen technology as well as scaling industry.

Questions on popular opinion and ethics were also explored. Germany's renewables are not sufficient for its energy needs, leading it to turn to power from other countries that are not necessarily reliable. Eventually hydrogen or electricity could be supplied from abroad, but the general public is generally against the idea of their electricity being controlled by another country. Ethical questions include the debate on phasing out nuclear power.

The participants agreed that we need a sense of urgency and that there are no one-size-fits-all solutions. Ultimately, solutions that are cost-effective will encourage countries to act. Promising solutions include energy efficiency, thorium-based nuclear power, hydrogen, a common carbon price, and emissions disclosures from companies.

Energy
Future Prospects of Global Energy Mix

[Chair]
Yeh, Nai-Chang, Professor, Physics, California Institute of Technology (CALTECH), U.S.A.

[Speakers]
Kodama, Toshio, President, Japan Atomic Energy Agency (JAEA), Japan
Ali, Ahmad Tajuddin, Chairman, Malaysian Industry-Government Group for High Technology (MIGHT); Chairman, Universiti Teknikal Malaysia Melaka, Malaysia
Xiansheng, Sun, Secretary General, International Energy Forum (IEF), Saudi Arabia
Piketty, Laurence, Deputy Chairman, The French Alternative Energies and Atomic Energy Commission (CEA), France
Zacharia, Thomas, Director, Oak Ridge National Laboratory, U.S.A.
Wongtschowski, Pedro, Chairman of the Board of Directors, Administrative Council, Ultrapar Participações S.A., Brazil

Opening Remarks

The chair opened the session by noting that all energy forms have respective issues that require discussion. There is general consensus that proper energy mix should be based on energy security, economic efficiency, environmental preservation, and safety, as well as technological advances in renewable and clean energy, reliable energy storage, and IT-based smart grids. However, other aspects are also important, including regional strategic planning, public policy, dynamic adaptation, public-private partnerships, and international cooperation.

Chair: Yeh, Nai-Chang

There was then introduction of the Japanese concept of 3E+S (energy security, economic efficiency, and environment + safety). Public acceptance, policy, and regulation are also essential components when considering energy mix. Japan is increasing the share of

new power sources such as renewables, but nuclear energy is still important. The Japanese government is thus launching a new initiative for the nuclear innovation promotion, Nuclear Energy × Innovation Promotion (NEXIP), with a view of advancing nuclear technology with excellent safety, economic competitiveness and mobility.

There was then a focus on developing countries that have small economies such as Malaysia and how they differ in their approach to climate change. These countries are aware of issues such as global warming but are still pursuing plans for non-renewable energy sources to meet their local needs. There is a push toward renewables in these countries but they have limited options, and developed countries should be understanding of this.

The International Energy Forum (IEF) was then introduced. It has a membership of many different countries and coordinates accumulation of data for JODI-Oil and JODI-Gas. The IEF holds many meetings in Riyadh regarding future energy mix. The meetings have shown that by 2040, fossil fuels will still be largely used with gas playing a more important role, and renewables will have developed quickly to constitute about 25% of the mix. Strategies and policies, new technologies for energy transition, and international collaboration are all important for energy mix.

There was then an introduction to the French Alternative Energies and Atomic Energy Commission (CEA), a public research organization that focuses on low carbon nuclear and renewable energies among other matters. In response to recent policies in France such as the Energy Transition for Green Growth Act, the CEA works with stakeholders to drive innovation and efficiency at affordable costs in line with local systems. It also focuses on international cooperation, such as for fusion with ITER which also has Japan's participation.

Oak Ridge National Laboratory was also introduced, and the need for aggressive energy sector decarbonization goals was discussed. Although costs for renewables have been driven down, there are still grid stability and other issues, leading some to argue that future energy needs cannot be achieved through renewables alone. Progress needs to be made in areas including stability, costs, battery technologies, IoT devices managing energy load, and machine learning.

There was also an assertion that increased energy consumption is good because it means higher GDP. The challenge is generating more energy with less carbon emissions. The speaker predicted that oil, biomass, wind and solar will continue to grow in the energy mix by 2040,

but hydrogen will only be relevant after 2040. Brazil's unique energy mix was highlighted, including its energy mix of 40% renewables and many flex-fuel cars.

Discussion

The discussion started with an examination of an energy roadmap including regional needs, financing and economics, business risk, safety, and more. The roadmap would enable the breaking down of complex problems and then customizing them locally. At the same time, creating a solution locally could also be expanded out to the world.

The discussion then turned to the recent surge of anti-science policies that could be disruptive to long-term sustainability, which strongly suggested the importance of education and outreach to the general public. There was also debate about nuclear energy being an option and dealing with public acceptance.

The participants agreed that there is no global solution, and energy mix will always depend on the nation. It was also acknowledged that developing countries are a large source of carbon emissions, yet they are far more constrained by economic considerations than developed countries. Ultimately, countries need to work with their original resources, so if they have coal, they will use it. Developed countries, companies, and philanthropy should take the lead in helping developing countries achieve energy mix goals.

Many different issues must be examined to increase renewables in the energy mix. Stability issues will continue to largely relegate renewables to a complementary role. Solutions include improving stability with batteries, smart grids and AI to understand and manage peak times, using natural gas, and energy efficiency. Overall, local solutions should be the focus in both developing and developed countries.

Life Sciences
Healthy Aging and Preventive Medicine

[Chair]
Block, Gene D., Chancellor, University of California, Los Angeles (UCLA), U.S.A.

[Speakers]
Akiyama, Hiroko, Professor Emeritus, Institute of Gerontology, The University of Tokyo, Japan
Minevich, Mark, Partner, Going Global Ventures Inc; Senior Fellow and Executive in Residence, US Council on Competitiveness and Hanaco Ventures, U.S.A.
Quirion, Rémi, Chief Scientist of Quebec, Canada
Tomita, Eiko, Vice President of Global Regulatory Sciences Japan/Korea/Taiwan Executive Officer, Bristol-Myers Squibb Company, U.S.A.
Hildebrand, John, Foreign Secretary, National Academy of Sciences; Regents Professor, Department of Neuroscience, College of Science, University of Arizona, U.S.A.
Hamaguchi, Michinari, President, Japan Science and Technology Agency (JST), Japan
Kennedy, Brian, Distinguished Professor of Biochemistry and Physiology, Yong Loo Lin School of Medicine, National University of Singapore (NUS); Director, National University Health System (NUHS) Centre for Healthy Ageing, Singapore

Opening Remarks

Chair: Block, Gene D.

The chair opened the session by talking about the effects of aging on circadian rhythms. The circadian network regulates the sleep/wake cycle. Aging affects this system profoundly, resulting in unhealthy sleep, which has comorbidity with other diseases. Quality sleep is therefore very important for healthy aging.

Next, the speakers discussed longer average life-expectancies. Societies aim to maximize the ability of people to live healthy and fulfilling lifestyles, in a socially and economically sustainable way. However, existing infrastructure and norms are not suited to this. Healthy aging requires a holistic approach

combining medicine and socio-economic measures. It should also encompass all life stages, not just old age.

The speakers then turned to AI and aging. As the global population ages, associated costs will also balloon. AI can transform our lives and healthcare, including earlier and more accurate diagnosis, better drug discovery, the creation of the Internet of medical things, greater use of robotics, more precise treatments, and advances in regenerative medicine.

Next, the speakers considered aging research conducted by Québec, such as human cohort studies about the factors that contribute to healthy aging. Exercise and socialization were found to be even more important than nutrition. Additionally, Québec's scientists are using the LOU rat strain as a model of successful aging. Québec has also launched out-of-the-box research, such as studying Alzheimer's without focusing on tau or amyloids.

Another topic of discussion was preventive medicine, which can help prolong healthy life-expectancy. However, it takes time to provide evidence to verify the efficacy, safety and quality of medicine, even more so for preventive medicine. Huge amounts of data are also required. Therefore, more innovative ways of providing scientific evidence are needed. Health authorities should also employ more efficient registration and review processes.

The 2017 G7 statement on the challenge of neurodegenerative diseases in an aging population was also mentioned. It highlights the devastating impact these diseases will have on society and recommends international research collaboration, improved clinical trials and cognitive tests, and better programs that also take into account the challenges of caregivers, all of which requires investment by governments.

Then, the speakers discussed rapidly aging and declining communities in Japan. They considered two cities with some of the lowest life-expectancies in Japan. Research on one found nutrition and activity to be very important to healthy aging. For the other city, community-led activities, involving a wide swathe of society, completely reversed its low life-expectancy, demonstrating the importance of multi-stakeholder collaboration.

The speakers also discussed disease prevention. Aging increases the rate of chronic diseases and reduces biological functions. Finding a way to slow aging is therefore key. Healthy lifespans have already been extended in animal models. Various promising avenues

for applying these results in humans have emerged, but they will require progressive support and risk-taking on the part of governments.

Discussion

A group discussion was then held. The participants first considered the need to change incentives around care providers and care systems, which will determine how research and investment are conducted. It could also correct the imbalance between investments which are currently more focused on short-term benefits and challenges such as aging, which are long-term.

The group also looked at the need to balance solutions for infectious diseases and non-communicable diseases, the former affecting developing countries more, and the latter affecting developed countries more. Perhaps this offers an opportunity for collaboration, with developed and developing nations learning from each other's challenges and experiences.

In addition, the participants discussed palliative care. They believed that patients should be able to make informed decisions about what care they receive. Furthermore, care should also encompass mental aspects.

Next, the participants spoke about data. Being able to use data from a wide range of sources would facilitate more efficient medical studies. There should also be harmonization and collaboration among countries so that regulatory authorities can accept data more readily. However, this also raises important issues relating to privacy protection.

Biomarkers were also discussed. It may become possible to monitor aging with biomarkers. However, questions remain about their accuracy and comprehensiveness.

The group then mentioned the need for prevention to include many different stakeholders who can influence the community, and the benefits of taking into account the needs of all generations of the community.

In addition, the group discussed the potential of AI to identify new frontiers in aging, but also caveats around its use, including ethical issues, concerns around data collection, regulatory management, and access. These can only be adequately tackled with government intervention and regulation, and international collaboration. In addition, it is essential to build trust around AI in communities.

Lastly, the participants highlighted the need for funding agencies to also invest in high-risk, high-reward projects. They should also be patient with young researchers, who may need more time to produce results.

Life Sciences
Microbiome and Health

[Chair]

Steen, Tomoko Y., Professor, Department of Microbiology and Immunology, School of Medicine, Georgetown University, U.S.A.

[Speakers]

Liu, Fu-Tong, Vice President, Academia Sinica, Taiwan

Hayashizaki, Yoshihide, Program Director, Preventive Medicine and Diagnosis Innovation Program, RIKEN, Japan

Weersma, R.K. (Rinse), Gastroenterologist, Head of the Department and Full Professor, Department of Gastroenterology and Hepatology, University Medical Center Groningen, University of Groningen, Netherlands

Honda, Kenya, Professor, Department of Microbiology and Immunology, Keio University School of Medicine; Team Leader, Laboratory for Gut Homeostasis, RIKEN Center for Integrative Medical Sciences, Japan

Suzuki, Rami, Head, Medical Affairs Division, Janssen Pharmaceutical K.K., Japan

O'Huigin, Colm S., Adjunct Professor, Department of Microbiology and Immunology, Georgetown University Medical Center, U.S.A.

[Voluntary Speakers]

Colwell, Rita R., Distinguished University Professor, Center for Bioinformatics and Computational Biology, University of Maryland College Park; Professor, Johns Hopkins Bloomberg School of Public Health; former Director, National Science Foundation (NSF), U.S.A.

Opening Remarks

To open, the chair highlighted the growing recognition of the importance of the microbiome to human health. At the same time, she pointed out the difficulty of studying microbiomes given how many factors they are affected by and the extent to which they differ among individuals.

The speakers then discussed how, as the study and understanding of infectious diseases have transitioned to a polymicrobial understanding of diseases, the study of the microbiome has taken on higher importance. Furthermore, the scope of microbiome research and application is broader than humans and their health. In addition, greater standardization in the study of the microbiome is needed to ensure more accurate understanding of the microbiome.

Chair: Steen, Tomoko Y.

Next, the speakers considered research concerning the role of microbiota in various cancers, as well as potential differences in the microbiomes among different populations and ethnicities, and how this could affect potential treatments. Promising advances are also being made in the culturing and identification of microbiota. In addition, inclusion of microbiota in biobanks could be very useful for furthering research.

The speakers then spoke about how next-generation-sequencers have significantly enhanced biological sequencing. They also considered the features of the human microbiome, such as its complexity and vast size. These features mean it can only be studied with huge and comprehensive data, which will require international collaboration. In addition, the speakers discussed the wide range of microbiome-related applied research that is occurring. To develop the industrial application, especially drug discovery based on the microbiome, we need to clarify the effective components (bacteria or phages) and the molecular mechanism of how the microbiome affects human disease phenotypes.

Chronic diseases of the intestines were then raised. The study of microbiome sites in the gut could yield new insights into various diseases. Nevertheless, microbiome research is still at an early stage and a better understanding of the microbiome is required before it will be possible to move into rational therapies. Collaboration among researchers, industry and regulators will also be needed.

The speakers then turned to live bacteria therapeutics. While fecal microbiota transplantation aimed at restoring microbiological diversity has been shown to be effective in treating diseases, the results are still inconsistent, due to uncertainty about the microbiological composition. Live bacteria therapeutics are more effective, as they are composed of well-characterized bacteria. They have been further enhanced by gnotobiotic approaches for identifying and isolating defined microbiological communities.

The work of the Janssen Pharmaceutical Companies of Johnson & Johnson was also discussed. The company sees potential in and is conducting microbiome-related research in an intentionally broad range of fields. In addition, the company values and actively pursues diverse partnerships. Through cooperation and collaboration with scientists and entrepreneurs, it is aiming to produce innovations in microbiome-related fields.

Lastly, the speakers noted that the current research paradigm is quite binary, looking at good or bad microbiota, or diverse or non-diverse microbiomes. This has yielded results, but deeper analysis is necessary. The speakers also considered research on the potential relationship between the microbiome and checkpoint inhibition immunotherapy for cancer, as well as a study involving laboratory mice and wild mice, which showed that a change in the microbiome can change the nature of the immune response, even in mice with similar genetic makeups.

Discussion

Following this, a group discussion was held. First, the participants wondered about the potential effects of climate change on the microbiome, such as pollution on the skin microbiome or the effect of oceans on the microbiome.

They also talked about the potential of phage therapy, which had been falling out of fashion, but is becoming relevant again as a potential avenue for creating novel therapies in response to anti-microbial resistance.

The participants also discussed the relationship between the diversity of microbiota and healthy aging. Some studies show that as people age, their microbiota become less diverse. In addition, the participants noted that currently, it is only possible to understand a snapshot of the microbiome, which is dynamic and continuously changing. The timeframe of analysis is very important.

The group also recognized the need for a holistic approach to data collection and data analysis that balances physical conditions and circumstances, noting that daily circumstances, such as diet, can affect the microbiome.

Another subject was probiotics. Probiotics have become very popular but there is a relative lack of understanding about the effects, and about what the microbiome actually needs. Further study and regulation are probably required.

Next, the participants turned to the need for standardized methodologies for characterizing microbiomes. Not only data but also metadata are required. Careful thought should also be given to how sequencing datasets are curated. Other considerations include the types and level of fiscal and human resources that should be dedicated to these efforts, and the need for accurate and reproducible tools for collecting data in the real world.

Lastly, the group called for comprehensive and focused studies that combine multiple approaches, such as culturomics and genomics. In addition, studies should start at the regional level, before moving to the national and international levels.

Life Sciences
Advanced and Precision Medicine and Bioengineering

[Chair]
Hirano, Toshio, President, National Institutes for Quantum and Radiological Science and Technology (QST), Japan

[Speakers]
Darzi, Ara,Professor of Surgery, Faculty of Medicine, Imperial College London, U.K.
Lévy, Patrick, President, Université Grenoble Alpes, France
Hirotsu, Takaaki, President & CEO, HIROTSU BIO SCIENCE INC., Japan
Elo, Laura, Professor of Computational Medicine, University of Turku, Finland
Fire, Andrew Zachary, Professor, Departments of Pathology and Genetics, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2006 (Physiology or Medicine)]

Opening Remarks

To start the session, the chair pointed out that technological advances have opened the way for advanced treatments and precision medicine. He explained that the session would deal with the new possibilities that have been realized, as well as the problems that remain to be resolved.

Chair: Hirano, Toshio

The speakers first considered the conceptual change in medical practice to precision medicine. In the UK, this change is being driven by escalating healthcare costs, the changing nature and demand in healthcare, and technological progress that enables more precise understanding of populations and more precise treatments. Examples of new interventions are surgical interventions in the gut microbiome, rapid evaporative ionization mass spectrometry, and sensing technologies for detecting sepsis. Population-level data and analytics also offer exciting possibilities.

Next, the speakers discussed chronic diseases, which are a major and costly challenge for society, affecting a large portion of the global population. Environmental changes, including socio-economic factors, also exacerbate the risk of chronic disease. Université Grenoble Alpes is exploring methods that combine measurement of important biological factors, for example using wearable devices, and omics, which would enable prevention, early risk detection, and the design of multi-phased interventions.

New developments in cancer screening were also discussed. Cancer screenings are important for detecting cancer at an early stage. However, such screenings need to be inexpensive and highly accurate. A new possible method is biological diagnosis using the olfactory system of C. elegans. Known as N-NOSE, the method is highly sensitive and specific, and a test would cost less than 100 US dollars.

Another topic was early biomarkers of diseases. Advances in omics technologies, and data collection and management, have increased the potential of identifying such biomarkers. Still, multidisciplinary teams that include computational and statistical experts are needed to make sense of the data. Another challenge is the lack of reproducibility. This can be overcome with vigorous data-analysis techniques, the application of proper standards, and more resources.

The speakers then discussed the role of people in precision medicine. A key question is how to educate future doctors, who will need to undergo traditional medical training, while also understanding these new and advanced techniques. Another concern is how to enable physicians to spend adequate time with patients. It is also important to ensure that the medical sector undergoes revolutionary changes, rather than just evolutionary changes.

Discussion

The participants then engaged in a group discussion. They first talked about the patient's perspective. Science and technology are advancing faster than policy and regulation, and it is important to prepare patients for new technologies, such as through public-patient involvement and engagement. Patients should be empowered to make informed decisions. The disease of loneliness and potential technology-based treatments were also considered.

The participants also talked about concerns related to data use and ownership, as well as the use of bio-banking to effectively share data.

It was also pointed out that digital transformation will affect society in many ways, one of which is to significantly increase the productivity of the healthcare sector.

Another topic was individualized care. It is necessary to take into account the personal circumstances, emotional states, needs and so on of individual patients. Furthermore, as medicine continues to advance, it is hoped that it will be possible to apply combinations of therapies that are suited to individual patients. However, this will surely be expensive and continued technological development will be needed to reduce the costs.

The group also held further discussions on the use of C. elegans for the early detection of cancer, as a solution with high specificity, high sensitivity and low cost. Further research is needed but this technology is very promising.

In addition, the participants talked about bioinformatics and data collection, and raised a number of questions: Do patients understand why data is collected and how it is relevant to their lives? Will data be used for common diseases or rare diseases? Will the data be anonymized? How will it be stored? Can consistent data collection be ensured? They also acknowledged the importance of international and interdisciplinary collaboration.

Lastly, the participants wondered what kind of healthcare system would exist in a perfect world, considering factors such as education, the nature of healthcare providers, human behavior, what data to collect and how, how to empower people to be able to collect data for themselves and better manage their own health, and how to pay for such a healthcare system.

Engineering and Innovation
Industrial Innovation

[Chair]
Hashimoto, Kazuhito, President, National Institute for Materials Science (NIMS), Japan

[Speakers]
Crawley, Edward F., Ford Professor of Engineering, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology (MIT), U.S.A.; Founding President, Skolkovo Institute of Science and Technology, Russia
Jackson, Keoki, Chief Technology Officer, Corporate Engineering, Technology and Operations, Lockheed Martin Corporation, U.S.A.
Liao, Marvin, Vice President, Advanced Packaging Technology and Service, Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC), Taiwan
Nishihara, Motoo, Executive Vice President, CTO (Chief Technology Officer) and Member of the Board, NEC Corporation, Japan
Ohno, Hideo, President, Tohoku University, Japan
Evans, Chad, Executive Vice President, Council on Competitiveness, U.S.A.

Opening Remarks

Chair: Hashimoto, Kazuhito

The chair began the session by noting that innovation was a key driver for the future of global society. The contribution of industry and academia is essential to achieving this goal. One effective approach to supporting industrial innovation is by creating synergies between government and industry, as well as promoting research and commercial incentives for organizations and individuals.

Next, the speakers discussed industry and university collaboration. Universities can contribute to innovation and societal goals such as through accelerating and encouraging entrepreneurship, as well as promoting knowledge exchange. Specifically, universities can contribute through fundamental activities in the areas of research, education, and innovation catalyzation, and by actively engaging various stakeholders in industry, academia, and government.

Another subject of discussion was the success of industrial innovation. Industrial innovation's reliance on extensive data, customer feedback, and expertise, are several reasons why it has been a driver for global society in recent years. Adaptive innovation models that allow for agile response to market conditions, while continuing to maintain focus on transformative technologies are important, as well as continuing to develop human resources and advocating research expansion across borders.

The speakers then turned to semiconductor technology. Technology advancement in this space has multiplied substantially over the last several decades, leading to massive innovation globally. However, this pace of development will begin to slow soon, and new methods, materials, and approaches will be required that ideally adopt a flexible nature to maximize a diverse array of strengths.

Next the speakers spoke about the importance of accelerating human resources learning and innovative university R&D approaches. With the pace of technological development, a multidisciplinary, flexible approach is required – which is why universities are uniquely placed to create value in a digital world. Institutions should be further leveraged and transformed to become bases of innovation. Skilled engineers should also be provided with a flexible ecosystem to leverage their abilities to contribute to innovation.

Then the speakers discussed mechanisms for promotion of innovation. Academia-industry collaboration is a key driver in this area, however there is often no visible revenue streams. ESG investments which focus on environment, social and governance are is one such vehicle for innovation. Given the importance of sustainability, approaches that encourage stakeholders to tackle important social issues collectively and with responsibility shared across the board are essential.

Lastly, the speakers took up the importance and challenge of sustainability in innovation. Maintaining and raising living standards across the world at scale, while maintaining sustainability will be a major challenge for global society. Advancements and innovation in agriculture, production and manufacturing, and energy that meet growing societal concerns will be essential to meeting this high-level goal.

Discussion

A group discussion was then held. The participants first dealt with collaboration between university and industry; high impact research papers; intellectual property rights; and the struggles of SMEs vs large companies in collaboration between academia and industry.

The participants also discussed innovations vs academia and research vs business; pros and cons of sustainability; and history of innovation over recent human history.

Next, discussions concerned how universities can help in fostering innovation with industry by creating more channels for collaboration; and the role of government in creating the link between academia and industry as well as defining technological innovation as it relates to sustainability.

They then discussed top-down and bottom-up approaches to innovation; industry backed innovation to overcome risk-aversion; community outreach as a result of natural disaster occurrence; strategic long-term approaches of large industry; and entrepreneurship-based learning in academia.

Engineering and Innovation
New Engineering Technologies

[Chair]
Gather, Ursula, Rector, TU Dortmund University, Germany

[Speakers]
Liao, James C., President, Academia Sinica, Taiwan
Matsumoto, Hiroshi, President, RIKEN, Japan
Murata, Daisuke, President & CEO, Murata Machinery, Ltd., Japan
Shah, Rajesh, Co-Chairman and Managing Director, Mukand Ltd., India
Stoddart, Fraser, Board of Trustees Professor of Chemistry, Department of Chemistry, Northwestern University, U.S.A. [Nobel Laureate 2016 (Chemistry)]
Varasi, Mauro, Senior Vice President, Technology and Product Innovation, Leonardo SpA, Italy

Opening Remarks

The chair began the session by stating that scientific progress is driven by curiosity and the spirit of discovery. Seldom do scientists have clear economic goals with their research at the outset. We should ask ourselves what are the major technological developments which will have impacts on the future, such as the Internet of Things, AI, and so forth.

Chair: Gather, Ursula

Next, the speakers discussed the difference between essential technologies, such as those combatting global warming, and non-essential but highly beneficial technologies, such as quantum materials development. Curiosity driven research is generally done by public funding, while mission driven research tends to be privately driven. Moving forward, we should emphasize flexibility in pursuing both kinds of research in both the public and private sector.

The speakers then spoke about the need for institutions and countries to work together to tackle global issues. Coordinated broad approaches are required reaching across

different stakeholders, and efforts must be put into vision-driven engineering. Research institutes have contributed towards the affluence of science over the years, however technology has also been utilized for darker purposes. There is never a guarantee that ethics will move forward hand in hand with technological advancements. It is therefore key that researchers have a clear vision of the future they are trying to create and communicate this clearly to all relevant stakeholders including the public.

Another subject of discussion was the purpose of engineering and challenges in technological manufacturing. How to correctly convey design intention to various stakeholders has been a major challenge of manufacturers. New technologies have given manufacturers the opportunity to get the job done easier, and IT can help achieve various industries connect with one another in new and exciting ways. The essence of industry is where these various forces come together to create real value.

The speakers then turned to the application of new technologies in the steel industry to work towards greater sustainability. Classic steel manufacturing methods such as via blast furnace can have detrimental environmental effects – therefore methodologies such as recycling steel or improving manufacturing efficiency will be long term goals for the industry. AI, robotics, and other new technologies can help develop dynamic models that lead to energy consumption improvements, cleaner output, and help achieve these important goals.

Next the speakers discussed curiosity and the need to enable curiosity in others, particularly the younger generation. Creativity and the acceleration of serendipity is also important for future research. Fundamental research is the environment, coupled with freedom given

to young researchers, that will lead to positive change in the world. Top down, hierarchical approaches are the norm in many research facilities – however this can stifle and demotivate the next generation of researchers and should therefore be discouraged. Networking can also be incredibly important to garner financial and public support for fundamental research.

Lastly speakers discussed digital and quantum technology application in the aerospace, defense and security industries. These two technologies represent new and challenging innovations in our industry. For example, with digital, big data has helped to create value with new state-of-the-art radar sensors. Furthermore, quantum technology will help launch a new frontier for sensor technology, amongst others, in cooperation with academia.

Discussion

A group discussion was then held. The participants first discussed creativity for students and the balance of providing guidance and freedom; the impact of AI and robots research and its role in supporting research; recognizing the importance of interdisciplinary collaboration; and promotion of testing and sharing to bring down barriers for cooperative research.

The participants also discussed the relationship between mission and vision driven research; innovation using startup companies; and the utilization of AI and supercomputers to enable accelerated efficiencies in the lab.

They then discussed conducting innovations in companies through brainstorming and discussion as well as at wider public forums; the sharing of innovations and fostering of better communication between industry and academia via government; fundamental research vs mission driven research; and how populist policies may affect research.

Next, discussions included curiosity and mission driven research and finding the ideal balance; the importance of curiosity-based research where new discoveries can provide unique insights; conducting research with society in mind and wider engagement with other scientific disciplines; and international cooperation in scientific research.

Lastly, developing engineering technologies that are relevant to solving crucial problems in the world; AI, hardware technologies, the future beyond Moore's Law; solving global issues such as food shortage and global warming; and increased regulation in terms of taxation for the private sector to solve such problems were discussed.

Engineering and Innovation
Robotics and Society

[Chair]

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

[Speakers]

Mohr, Catherine, President, Intuitive Foundation, U.S.A.

Fukuda, Toshio, IEEE President (2020); Professor Emeritus of Nagoya University; Professor of Waseda University, Meijo University and Beijing Institute of Technology, Japan

Mason, Thomas, Director, Los Alamos National Laboratory, U.S.A.

Asama, Hajime, Professor, Department of Precision Engineering, The University of Tokyo, Japan

Stone, Morley O., Senior Vice President for Research, Office of Research, The Ohio State University, U.S.A.

Kheddar, Abderrahmane, Director of Research, CNRS-AIST Joint Robotics Laboratory, Japan; Full Member, National Academy of Technologies of France (NATF), France

Dario, Paolo, Professor of Biomedical Robotics, The BioRobotics Institute, Sant'Anna School of Advanced Studies - Pisa, Italy; Professor, National Thousand Foreign Talents Program, School of Mechanical Engineering, Tianjin University, China

Chair: Johnson, Ray O.

Opening Remarks

The chair began the session by noting that robotics and automation have been useful in many societal sectors. They have helped increase efficiency, reduced accident rates, and have overall historically been well accepted by society. However, some newer technology such as AI and drones have split public opinion.

Next, the speakers discussed the Japanese experience of robotics and usages in disaster relief situations. Robotics can help mitigate risk for human first responders in Japan, where natural disasters such as earthquakes, typhoons, and landslides occur frequently.

Unlike well-structured environments found in factories, robotics must be adapted for usages in unpredictable places such as in tsunami-stricken areas. Given such challenges, training for both robotics and operators will be paramount to creating effective technologies. Regulations, certifications, and other areas are also important to discuss, and we can share best practices and experiences internationally across borders.

The speakers then spoke about the future of robotics. Robotics combined with new technologies such as AI will help solve major issues related to aging society, agriculture, weather climate, energy and so forth. Working at multi-scale levels and internationally with partners globally is paramount to achieving these goals. Other important future robotic technologies include bio robotics, micro- and nanorobots inside the human body, cyborg and hybrid bionic robotics and autonomous robotics to improve the quality of life. Insurance and regulatory bodies must also be more heavily involved in the discussion going forward. Finally, it is essential that we keep ethics in mind in the discussion of robotics.

Another subject of discussion was regarding robotics' impact and role in society today and in the future. The role of robotics has been enhanced due to technological capabilities over the years, augmenting the capabilities of humans. Examples include going to Mars and drone technology allowing for more effective searching of fugitive methane emissions, inspections of wind turbines, and forest fire fighting. This advanced mechanization has allowed humans to focus on more intellectually stimulating subjects. Current discussions around technologies such as AI have posed questions around the relationship and positive or negative effect it will have on mankind and society.

Next the speaker discussed the usage of data in the healthcare field and in the training of surgeons. Traditionally surgeons have been taught in the apprenticeship model. Introducing robotics has allowed for an observed learning process, opening the ability to apply data and analysis in ways we could not prior. There are 5 billion people globally who have no access to basic surgical services – this translates into millions of excess deaths a year. By observing a novice practitioner transitioning into an expert, we can develop AI coaches to train and share global best practices. Building global data commons will be a key enabler of addressing this issue.

The speakers then turned to the autonomy of robotics. As routine and more complex tasks become automated, the role of humans becomes more rather than less important. We need to understand how to place the human operators within this framework, which requires a different approach to computer science, engineering training, and coursework. In addition, user acceptance and underattended areas of research such as team science, team performance over time, and mixed teams of human and AI should be bolstered. Community engagement and impact can also help respond to the rapidly changing landscape of robotics.

Next, the speakers spoke about the future of robotics and approaching challenges. Making robots interact with humans is more difficult than automation, given the inherent complications. The computational speed of AI has improved immeasurably, as has our access to data. Another hurdle for bringing robots and humans together is certification – currently it is non-existent. Also, partnerships must be created between academia and industry for improved knowledge sharing capabilities.

Lastly the speakers took up the subject of bio-robotics. Body intelligence is not only the brain, but joints, muscle structure, and other organisms. Integrating science with social sciences can help us bridge the gap between biology and robotics. We should also consider the advantage of sharing collaborative actions between humans and robots, new materials and manufacturing for robotics, and how robotics can help combat major issues such as global warming.

Discussion

A group discussion was then held. The participants discussed open data as a foundational platform; how to accelerate robotics learning; using robots to amplify capabilities; a need to change or modify legal platforms; and definitions of robots – what is a robot and what comes next.

The participants also discussed various types of robots; fundamental robotic technology and its role in society; the lights and shadows of robotic technology and inherent risks; regulation in robotics; and ethics in relation to robotics.

They then discussed categories of robots including “traditional” robots; harnessing power from the environment to power robotics; robotics utilized in warfare; the physical limitations of robotics in working within human environments; robotics working in highly radioactive environments such as nuclear power plants; education and training related to robotics; and maintaining the balance between academia and industry in robotics research.

Environment

Adaptation to / Mitigation of Climate Change

[Chair]

Korhola, Eija-Riitta, Delegate, Consultative Commission on Industrial Change, The European Economic and Social Committee; former Member of the European Parliament (1999-2014), Belgium

[Speakers]

Watanabe, Chiho, President, National Institute for Environmental Studies (NIES), Japan
Le Gall, Jean-Yves, President, National Centre for Space Studies (CNES), France
Luers, Amy, Executive Director, Future Earth, Canada
Lee, Yuan Tseh, President Emeritus, Academia Sinica, Taiwan [Nobel Laureate 1986 (Chemistry)]
Pereira, Joy Jacqueline, Principal Research Fellow, Universiti Kebangsaan Malaysia, Malaysia
Keith, David, Gordon McKay Professor of Applied Physics and Professor of Public Policy, Harvard University, U.S.A.
Mutoh, Jun, Representative Director and Executive Vice President, JXTG Holdings, Inc., Japan

Opening Remarks

Chair: Korhola, Eija-Riitta

The session opened with the chair discussing how, historically, climate conferences have treated adaptation and mitigation as mutually exclusive alternatives, when in reality both are necessary. The Kyoto Protocol was viewed as an undesirable solution; the price of unsuccessful mitigation. However, mitigation alone will not suffice, and developing countries and vulnerable populations are demanding adaptation and preparedness. Still, there remains the question of whether adaptation policy should be on the international agenda or dealt with on a national level.

The speakers then moved on to talk about human ecology and the cost of climate change for developing countries and future generations. They stressed the important roles of scientists, science-based NPOs, and policy makers as unique communicators with the general population. While technological innovation is welcome, they need to be fully evaluated for their potential risks. Societal innovation is essential, and we must convey a message to promote the sense of ownership of the issue among the public.

Next, the speakers looked at the need for global monitoring in making informed and coordinated decisions. Satellites are an important tool in this, and space agencies share a special responsibility in detecting climate change. The speakers then spoke of the challenges of the technology and how satellite data must be interpreted to use safely in prediction models. It was added that artificial intelligence (AI) also offers great possibilities to benefit from this data.

Following this, the speakers discussed the global sustainability agenda, and how it is critically important to have an international perspective and look at the flows and connections between sectors of the world when building adaptation plans. The digital revolution provides many opportunities for us to think differently about these connections.

A common theme throughout the session was the state of emergency the earth is in, with a changing atmosphere and rising temperatures, and the need to promote international cooperation among organizations. It is not feasible for smaller developing countries to target zero emissions, so we need collaboration that goes beyond the scientific and to think of ways we can make clean energy available in the global market. To do this, we must reexamine what we mean by “need” and “development.” Funding for science and technology will be crucial.

Next, they looked at the effect of global warming on people worldwide, such as the threat to low-lying areas caused by rising sea levels, and the role of disaster prevention. They called for action; faster progress, new technology, greater collective ambition to reduce all greenhouse gases, leveraging of digital technology and satellite information, improvement of public access to information, and promotion of local science.

The speakers then discussed solar geoengineering, which could be utilized in combination with emissions cuts to address the local hazards resulting from climate change. The current questions are whether there should be a serious international open access research program on geoengineering integrated into mainstream climate and science research, and how these technologies might be governed in a divided world. It was emphasized that we

should discourage unilateral action today but develop the information that will allow the next generation to make an informed decision.

The speakers then examined climate change from a business viewpoint and the mitigation measures energy companies can put in place. These measures include zero-emission and carbon-free policies focused on using hydrogen, community development and the creation of a decentralized system of energy distribution to achieve optimized cities, and the creation of a circular society based around the recovery of rare metals and carbon recycling.

Discussion

A group discussion was then held. The participants raised the issue of the need for data, which is often incomplete due to funding and political issues. The policy side must be comfortable with ambiguity and create robust solutions. They recognized the need to empower the public with direct access to data, while the government must be informed by science and have a role in turning it into a narrative for the public. Additionally, standardization is needed to ensure compiled data is truly useful.

Following that, the discussion touched on the uncertainties of climate models and how extreme weather elements effect people.

Another issue raised was that of demographic issues, including the critical role of population growth and energy consumption per capita in global warming, and the need to make clean energy available for developing countries at a cheap price. The socioeconomic situation differs between countries and we must be to not only frame the discussion on lifestyle changes around developed countries. In Japan, internal migration combined with a decreasing population has led to less efficient energy consumption in rural areas, so relocation could be encouraged as an adaptation to climate change.

They also raised the question of resource efficiency that comes with electrification, and the tradeoff between carbon mitigation and increasing use of metal resources.

Environment

Marine Environment for Sustainable Society

[Chair]

Matsunaga, Tadashi, President, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan

[Speakers]

Ehrenfreund, Pascale, Chair of the Executive Board, German Aerospace Center (DLR), Germany; former President, Executive Board, Austrian Science Fund (FWF), Austria

de Halleux, Sebastien, Cief Operating Officer (COO), Saildrone, Inc., U.S.A.

Henocque, Yves, Chair, Coast and Sea committee, Foundation of France, France; Senior Adviser, International Relations Division, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan

Kirshner, Robert, Chief Program Officer for Science, Gordon and Betty Moore Foundation; Clowes Research Professor of Science, Department of Astronomy, Harvard University, U.S.A.

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

Westphal, Hildegard, Scientific Director, Leibniz Centre for Tropical Marine Research, Germany

Opening Remarks

Chair: Matsunaga, Tadashi

The chair began the session by explaining how the Earth's environment has been profoundly changed. The population has increased from one to six billion during the last 100 years, economic activity has increased ten-fold in the last 50, half of the Earth's land surface has been domesticated for human use, most fisheries are fully or over exploited, and the atmospheric composition is significantly different. Technology such as satellites and mobile phones have enabled monitoring of these changes, yet oceans, which are a key planetary system covering 70% of the globe that profoundly affect society, lack such dense and extensive monitoring data. Autonomous technology such as drones, monitoring buoys, and microplastic measurement devices are now becoming available, rapidly changing our scope for marine environmental science. Smart management of the coastal and marine socio-ecosystem, smart technology for monitoring, and promotion of understanding and awareness will be essential for the future sustainability of society.

The speakers then moved on to discuss the innovative possibilities of interdisciplinary research in understanding the maritime situation. There is a need for innovative technologies, such as the improvement and development of sensor technology for monitoring at a local and global level, airborne and space observation, big data analysis and the fusion of data from different sources, communication and navigation systems, new algorithms, and the further development of flight systems and high-altitude platforms.

Next, the speakers discussed the use of technology in monitoring the surface of the oceans. While satellites provide a big picture, autonomy, robotics, and renewable energy are being utilized to efficiently deploy sensors across the oceans to study the nexus of air and sea interfaces. The issue of funding was raised, and suggested solutions included supplementation from pioneering philanthropists and the acceleration of public-private partnerships.

The speakers talked about the many monitoring systems which require governance and stressed the importance of a multi-scale approach on not just a local and national scale, but a regional and global scale. The role of environmental groups in marine stewardship was brought up, along with their potential to achieve more than local authorities. The private sector must also be considered, and public-private partnerships will involve large corporations which exert much influence on industries such as fishing.

The speakers then addressed the role of charitable foundations in conservation and science, using the example of the Moore Foundation. These foundations can be willing to take risks and make decisions fast without the need for consensus, and so can accelerate the pace of scientific discovery. They can offer funding for marine science initiatives, help academic efforts, and identify gaps for technological opportunity.

It was noted that bridges between the academic community and policymakers are important. The speakers then discussed the place of hydrology with oceanography, and how looking at both the land and the ocean is important in monitoring the marine ecosystem. The oceans have a far longer retention time than rivers, meaning recognition of pollution takes longer. However, public awareness of ocean pollution and plastics is growing, and moves

toward recovery are being made. The speakers mentioned that the changes in the marine environment also affect the energy sector.

The discussion then moved onto what a changing ecosystem means for humans and their societal needs, the importance of oceans in providing nutrition, and the pressure population growth is putting on the oceans. The speakers noted that nutrition-related funding has tended to focus on the agricultural sciences. However, with fisheries overexploited, aquaculture is becoming increasingly important. We need to find a balance between producing proteins from seas and using aquaculture without damaging other ecosystems.

Discussion

Following the opening remarks, group discussions were held. The groups talked about the various issues facing oceans today, including plastics, microplastics, pathogens, red tides, and how these are impacting humans, as well as the need for regulations and standards in marine industries such as aquafarming.

A common theme was communication, citizen science, and making sure people, particularly in coastal environments, are armed with information. Data processing, availability, and accessibility is important, and the participants noted the amount of data available to scientists, while stressing that this data must reach the communities that need it in a

format accessible to them. Social and global-political factors should be considered, and we must acknowledge the importance of education at a regional level to encourage behavioral changes.

Next, the participants discussed interconnection and how changes in the marine system also affect our land ecosystem. There is a need for a cohesive, interdisciplinary approach and integrated management. It was suggested that analysis and resources should be available at different scales, potentially with a lead agency to coordinate this interconnective system. Outputs should be articulated for use in policy and be communicated to NPOs, stakeholders, and the public.

Finally, the participants touched on sustainability and how fostering open source platforms can help in analyzing data sets which can be critical for the sustainability of marine systems. There is also the question of where in the chain responsibility for sustainability should be addressed, for example, at the point of catching fish or at the point of consumption.

Environment

Environmental Change and Risks of Health

[Chair]

Hacker, Jörg, President, German Academy of Sciences Leopoldina, Germany

[Speakers]

Shimpuku, Yoko, Associate Professor, Human Health Sciences, Graduate School of Medicine, Kyoto University; Vice-Chair, Young Academy of Japan, Science Council of Japan, Japan [Future Leader 2018]

Dobner, Thomas, Scientific Director, Head of Research Unit, Heinrich Pette Institute, Leibniz Institute for Experimental Virology, Germany

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

Collins, Mary, Provost, Okinawa Institute of Science and Technology Graduate University (OIST), Japan

Tannock, Gregory Austin, Emeritus Professor and Burnet Institute Visiting Fellow, Burnet Institute, Australia

Oliveira, Marielza, Director and Representative to the People's Republic of China, the Democratic People's Republic of Korea, Japan, Mongolia and the Republic of Korea, United Nations Educational, Scientific and Cultural Organization (UNESCO), China

Chair: Hacker, Jörg

Opening Remarks

The chair opened the session by discussing how environmental changes are affecting health and related disciplines, such as environmental science, medicine, and infectious disease research.

Next, the speakers discussed how environmental issues are starting to receive more serious attention, but some countries require a change in mindset toward science. New combinations of different fields can lead to innovation, for example, nurses can help support communities in their adaptation to the impacts of climate change. The participants then stressed the need to directly involve citizens in science, increase general awareness of environmental effects on humans, and invest in citizen science at community, national, and global levels.

The speakers then turned to look at the impact socioeconomic and environmental changes, such as urbanization and global warming, will have on infectious diseases, which include newly emerging infectious diseases originating primarily in animals and reemerging diseases such as tuberculosis and polio. Disease outbreaks differ vastly in origin, effect, and transmission, but their commonality is that the global community lacks preparation and countermeasures. Pathogens have no borders, and increased mobility poses challenges for disease control. We need an integrated effort including improved vaccinations, global investment in prevention measures to eradicate pathogens and avoid future outbreaks, and preparedness measures for when prevention fails. Additionally, AI can be utilized to provide algorithms for predicting future outbreaks.

Another topic of discussion was malaria, which is the cause of half a million worldwide deaths annually. Extreme weather events will lead to more outbreaks, and a worldwide combination strategy is necessary. The speakers also discussed the possibility of eradication, and preventative measures such as mosquito nets, new antiplasmodial drugs, vaccine research and improved vaccines, community action, and insect surveillance. Improvements to technology and social care will also need to accompany climate change.

Next, the speakers looked at influenza, one of the most important of all human infectious diseases due to its variability, unpredictability, and tendency to produce pandemics. Vaccine manufacturers and regulatory authorities face huge problems. Most pandemic viruses spread from avians to humans, and the changes to migratory patterns caused by climate change will have a huge influence on what kind of viruses will arise. Data on the influence of avian patterns on disease will be crucial.

On the other hand, the issue of predictable risks was also raised, particularly the rise in dementia that comes with an increasing and aging population. Great advances in biomedical and pharmaceutical sciences have led to increased life expectancy, and with it comes dementia, the cost of which is 3-3.5% of GDP for the U.S., UK, and Japan. The participants also touched on the fact that women bear much of this invisible cost through the provision of informal care. In a sense, this too is a kind of pandemic.

Another topic discussed was how climate and health crises are interconnected and require new integrated frameworks. The speakers stressed education as a critical issue and the need to embed in our education systems not only an understanding of science, but also media literacy and critical thinking to combat movements such as climate change denial and "anti-vax." The importance of legal frameworks was also emphasized. Furthermore, investment in disaster reduction mechanisms, biotechnology, and social protection systems will be necessary.

Discussion

A group discussion was then held. The participants talked further about the problems of misinformation and stressed the importance of citizen science, climate education, and the normalization of vaccinations. Some countries, such as Australia, are actively creating documentation on these topics aimed at the public. Public consensus is required to drive political action, and nurses could act as mediators between governments and populations.

Considerations of an ecocentric point of view were raised, and of potential changes to the perception of animal rights. Additionally, the participants discussed emerging pathogens created by selective pressures, such as antimicrobial resistance created by feeding animals with antimicrobials and the overprescription of antibiotics by primary care physicians.

Concrete steps for disease prevention in the borderless world of viruses and pathogens were considered, such as the implementation at some airports of systems to detect passengers with elevated temperatures who would then be quarantined, and the potential use of algorithms for prediction.

The effect of climate change on influenza was discussed further. It is more prevalent in colder climates, so climate change may reduce prevalence in some parts, while causing the disease to move to other areas as they become warmer. The economic cost of an influenza pandemic could be huge. We will need preventative medicine that goes beyond national boundaries, and to improve human health in places where the vulnerability of the human populace intersects with the vulnerabilities of climate change. Non-infectious diseases and those related to demographic changes are also going to be an important consideration.

Cooperation in S&T

Science and Technology in Developing Countries

[Chair]

Handoko, Laksana Tri, Chairman, Indonesian Institute of Sciences (LIPI), Indonesia

[Speakers]

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

Hayashi, Nobumitsu, Deputy Governor, Japan Bank for International Cooperation (JBIC), Japan

Kaur, Inderjeet, DBT-Innovative Young Bio-technologist Award Fellow (IYBA Awardee/Fellow), Malaria Biology Group, International Centre for Genetic Engineering and Biotechnology (ICGEB), India [Future Leader 2018]

Kayashima, Nobuko, Vice President, Japan International Cooperation Agency (JICA), Japan

Natera, Angélica, Executive Director, Harvard University - Laspau, U.S.A.

Opening Remarks

The chair began the session by thanking the attendants for their participation and introducing the topics for discussion, focusing particularly on how the recent trend of Industry 4.0 brings many consequences for developing countries in terms of development, but also highlighting the importance of considering not only how Industry 4.0 can disrupt societies, but also how to take advantage of the great opportunities for innovation that become available through Industry 4.0.

Chair: Handoko, Laksana Tri

The speakers then discussed the need for more collaboration on research, particularly between developed and developing countries. The problems that every country face are global problems. What is important is to consider how to leverage exciting new technologies through improved collaborations, to solve serious issues faster with stronger research.

This was followed by talks about how business is the best method to tackling global challenges. In particular, if the obstacles of investment and infrastructure in developing countries could be overcome, it would be possible to improve and expand business in those countries, improving the quality of life for people living there.

Next the speakers discussed the problem of diseases in developing countries, and specifically the burden caused. Drug resistant and infectious diseases are increasing, as is the need for coordinated efforts to deal with the burden on affected countries. Collaboration between developed and developing countries would provide resources to make those efforts possible.

Then the topic of human resource development and education, in relation to science and technology, was discussed, focusing on the role STI have on the SDGs roadmap, and their importance for building a sustainable society. Academic exchange and collaboration are vital for improving human resource development, along with partnerships with developing countries.

Finally, the speakers talked about the need to strengthen and invest in universities, which are engines of scientific and social developments. It is important to accelerate the adoption of new technologies that empower students and professors, because technology brings extraordinary opportunities, but without the correct teachings, it will fall short.

Discussion

A group discussion was then held. The participants discussed the necessity of how, to understand science and technology in developing countries, it is important to have an understanding of the recent changes in the landscape of science and development.

They also raised the point that different countries face different challenges in terms of increasing the investment in science and technology. It is not enough to think of one solution to fit every country, because each country has different backgrounds and issues to address.

Then the topic of brain circulation and brain drain was raised, and it was agreed that the world is moving towards circulation over drain, but then the issue becomes how to use the resources effectively, especially since many developing countries do not have industries or institutes to keep talented people.

Next the issue was raised that, in developing countries, research goes into teaching, but it does not move further on, and that researchers are not being trained, because they focus on research rather than societal needs. There is a great need to tailor research towards those needs, in particular for developing countries that are more concerned with education and health problems than global issues like climate change.

The gender issue was also raised, and it was pointed out that for developing countries to improve the quality of life, everything needs to have better equality. It was also pointed out that the gender problem is not just in developing countries; it is also a problem for developed countries. What is important is for the institutions to decide how to address the issue.

This was followed by the idea of needing to provide a better ecosystem for science and business to cooperate together, with more interaction between businesses and academics, and the need for reform within each of those parties so they can better interact.

Finally, it was discussed that developing countries need to learn to collaborate and work together, not just chase after developed countries, because the problems they face are universal amongst them. Also, research parameters are set by the funders, which come from developed countries rather than developing countries, so the research is more geared towards their interests rather than being relevant for low income countries.

Cooperation in S&T

Collaboration among Academia, Industries and Government

[Chair]

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

[Speakers]

Chubachi, Ryoji, President, National Institute of Advanced Industrial Science and Technology (AIST), Japan

Goldstein, William H., Laboratory Director, Lawrence Livermore National Laboratory (LLNL), U.S.A.

Horiba, Atsushi, Chairman & Group CEO, HORIBA, Ltd., Japan

Makelane, Hlamulo, Research Fellow, Department of Chemistry, Nelson Mandela University, South Africa [Future Leader 2018]

Thomsen, Christian, President, Technische Universität Berlin, Germany

von Klitzing, Klaus, Director, Low Dimensional Electron Systems, Max Planck Institute for Solid State Research, Germany [Nobel Laureate 1985 (Physics)]

Dvorkovich, Arkady, Chairman, Skolkovo Foundation, Russia; President, FIDE, Switzerland

Chair: Marshall, Larry

Opening Remarks

The session began with the chair's introduction of the speakers and the topic, in particular the hope of improving collaboration to solve the world's problems. Working towards the idea of building a bridge between academia, industry and governments, the question becomes how to get such different groups to work together, when each have their own goals and agenda. The United Nations SDGs have created a good model for collaboration, but more incentives may be needed, and there needs to be a greater openness to change.

This was followed by the speakers discussing that there is a growing awareness of the realization of a sustainable society, and that there are serious issues to solve when proceeding with this. In particular, how to realize the creation of social value from a collaboration perspective from each field is crucial.

Next the speakers talked about how collaboration is essential for research and development progress, in order to have real world impact. The problem of creating structures and incentives for the sectors to work together remains. It is important to seek common ground and have a mutually beneficial division of labor.

Then the speakers considered recent collaboration between industry and academia, and how this kind of collaboration can contribute to innovation and new technology. But collaboration needs to be stronger to create the building blocks for a sustainable society, and in order to keep up with recent movements, ideas need to be shared at a globally competitive level.

The speakers then highlighted the gap between higher education, governments and industry, stemming from the private sector being all about profit, while governments have to protect society and so mainly fund the public sector. Nobody knows what the future will hold for these sectors, but they need to reconsider their goals for the future.

Next the grand challenges of social cohesion, climate change, global health and a digital future were discussed. Academic freedom at universities is important; innovation comes out of free thinking, while human resources from academia breed collaboration. The challenge is to find a model to make cooperation work. Also, involving industry without losing academic freedom is key.

The speakers went on to discuss that the goals of the different sectors are varied, as is the time scale and future thinking of each. In particular, if there is to be cooperation, governments should be making the environment to support this, because all sectors want to cooperate if there is something to facilitate it. Increased basic research in industry would facilitate cooperation between academia and industry, as product-related research is very often hindered by intellectual property (IP) discussions.

Lastly the speakers considered that it may be difficult to achieve three-way satisfaction. The relationship between sectors must involve compromise between short-term public

interest, the long-term good of the nation, and business that drives economy and creates value. Good dialogue between each sector will bring the sectors together, but incentives are equally important.

Discussion

Following the opening remarks, discussions were held on the continued need for collaboration especially with the SDGs, but also remembering that challenges and barriers are real, in particular the issues of differing time lines, IP, use of funding and legal issues. Some requirements that are needed to deal with this are ensuring common purpose and vision, clearly defined roles, and making incentives that are open enough to not close off innovative ideas, as well as building trust.

The participants next discussed the difficulties on collaboration between industry and academia, because of IP, which causes problems with competitors. Solutions for those difficulties include governments funding research and forcing industries to make their findings openly available. Furthermore, building trust amongst international companies would make it easier to share IP.

The participants then highlighted several success models from other countries and noted that some of the best results were seen in countries where politicians are technocrats, who consider the importance of science. They also noted that long-term rather than short-term partnerships create the best industry engagement.

They then discussed the challenges of collaboration, and that some are hard to overcome on a global scale. There needs to be good communication between industry and academics, and reduced regulations on IP to improve knowledge sharing. There is a danger of big companies not diffusing knowledge to society, so governments may have to intervene. In addition, there needs to be collaboration with society as well, and on a global scale to successfully transfer knowledge and help countries grow.

Then the point was raised that there need to be multiple models of innovation for different countries, because one size does not fit all. Additionally, the idea of mobility, people moving between sectors to broaden their perspectives and build idea networks, was also raised.

The discussions closed with comments about the need to enlarge the definition of who researchers are. Furthermore, it is important to consider how partnerships work in developing nations, and that governments could provide funds to encourage collaboration.

Cooperation in S&T

Science and Technology Diplomacy and International Collaboration

[Chair]

Kishi, Teruo, Science and Technology Advisor to the Minister for Foreign Affairs, Ministry of Foreign Affairs (MOFA), Japan

[Speakers]

Dallman, Maggie, Vice President (International) and Associate Provost (Academic Partnership)/Professor of Immunology, Department of Life Sciences, Imperial College London, U.K.

Leblebici, Yusuf, President, Sabancı University, Turkey

Travaly, Youssef, Vice-President of Science, Innovation & Partnerships, African Institute of Mathematical Sciences (AIMS), Rwanda

Green, James L., Chief Scientist, National Aeronautics and Space Administration (NASA), U.S.A.

Yamakawa, Hiroshi, President, Japan Aerospace Exploration Agency (JAXA), Japan

Mu, Rongping, Director-General, Center for Innovation and Development, Chinese Academy of Sciences (CAS); Dean, School of Public Policy and Management, University of Chinese Academy of Sciences, China

Mitra, Arabinda, Scientific Secretary, Office of the Principal Scientific Advisor, Government of India, India

Simonneau, Denis, Senior Vice President for Institutional Affairs, L'Oréal Group, France

Opening Remarks

The chair opened by highlighting the three dimensions of science and technology and diplomacy: science in diplomacy, diplomacy for science, and science for diplomacy. In recent years, coinciding with a great social transformation from digital technology, the number of internationally coauthored papers and activities is increasing year-by-year. The role of science, technology and innovation becomes more important, and practical understanding of science and technology is required, in addition to the traditional three dimensions. The question then becomes, are there any items that should be added to those dimensions, and what should be particularly emphasized and noted?

Next, the speakers discussed the idea that global challenges require global solutions, and such solutions come from the diversity of bringing people from across the world together.

Chair: Kishi, Teruo

Universities are very effective at bringing people together to work on such challenges and in this way contribute to the three dimensions of science and diplomacy. But at this time of increasing global scientific collaboration there is a rejection of globalization by marginalized parts of society. It is now more important than ever that we use our skills to support local partnerships and communities, to make people aware of the opportunities they can gain from being involved in science and that local and international endeavors are coexisting parts of a strategy that focuses on making a positive impact.

The speakers then talked about how the accelerating pace of science and technology requires openness and shared technology. Data among multiple actors and nations becomes key for building diplomacy, because it can create mutually beneficial relationships amongst parties. As long as the parties have a positive stake in sharing, it will lead to positive results.

Then the idea that science and technology and diplomacy should be looked at over the next 45 years was discussed, focusing on the African continent as a reference. The main point of the reference was that countries need to come together in a pan-African approach to develop skills for the good of the continent.

The speakers followed with a discussion on the Space Act and the resultant types of collaboration activities, including bilateral and multilateral activities. In particular, the activities relating to the International Space Station were shown as a strong example of successful and inspirational activities to provide a framework for countries to collaborate.

This topic was followed by a discussion on Japan's basic space law bringing contributions to international diplomacy and Japan's space endeavors, including using satellite observations to monitor potential disasters. Furthermore, developing countries can more easily take part in space programs through the Japanese Experimental Module which is part of the

International Space Station. Japan has made full use of the benefits gained from diplomacy for science, and used the technology gained therein for diplomacy.

The speakers then introduced the role science plays in diplomacy, with the future of humankind relying on technology. The question becomes how to promote international cooperation, strengthen international linkage, promote capacity building for science and manage the outcome and value of science and technology. The major issues involved in this include trust and capacity building.

This was followed by a discussion about how there can be more powerful science and technology collaboration amongst nations. Science and technology are expected to touch the lives of people and be a tool to ease the lives of citizens. It is inevitable that science and technology will be a tool for diplomacy around the globe.

The opening remarks ended with several examples of the links between diplomacy and science, and new issues where more cooperation is needed, such as the ever-accelerating evolution of technology and the new challenges for countries to adapt and understand them. The importance of sharing knowledge with other parties was also highlighted.

Furthermore, the speakers highlighted the need for international collaboration for achieving Sustainable Development Goals (SDGs) using Science Technology and Innovation (STI).

Discussion

A group discussion was then held. The participants discussed the need to improve the contribution of the global science elite to the regular citizenry, including enhancing science education and media literacy in society to improve trust in science. Also, the idea of training for teachers to improve scientific understanding in young children, and for scientists to learn how to explain their fields better, was raised.

The participants also discussed the lack of opportunities for countries to work with African countries, and the need to work together as a global community to face major challenges. Also, as with Africa, international organizations can look together for further exploration and resolution of property rights in space. Through collaboration, the results of space related issues can be used for local communities.

The participants then discussed how science and technology are becoming more prominent as a matter for foreign ministers, showing an increasing understanding of the importance of cooperation in this domain amongst countries. It is important for international and common understanding of the issues at stake. In addition, partnerships at regional and local levels would have important roles as much as international cooperation.

The participants then raised the issue that diplomacy, like science, is a slow process, and questions on future development should focus on how to tackle urgent issues, and how to raise trust in diplomacy when there are international agreements that have not been achieved.

The participants then highlighted the need to attract younger people to science, and make them take up science as a career. It is important to attract young people and improve brain circulation, to find a way to collect young and talented researchers.

Lastly the discussion turned to the question of how to create a collaboration between countries when there is little to no mutual interest. Topics such as infectious diseases differ between developing and developed countries, so it is important to build a strong dialogue between countries.

S&T and Society

Policy Making in Science and Technology based Society

[Chair]

Paquet, Jean-Eric, Director General, Research and Innovation, European Commission, EU

[Speakers]

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

Nemer, Mona, Chief Science Advisor, Government of Canada; former Vice-President of Research and former Director of the Molecular Genetics and Cardiac Regeneration Laboratory, University of Ottawa, Canada

Huber, Bernd, President, Ludwig-Maximilians-Universität (LMU) München, Germany

Matsuo, Seiichi, President, Nagoya University, Japan

Kossowska, Małgorzata, Chairwoman of the Council, National Science Centre (NCN), Poland

Fall, Chris, Director, Office of Science, United States Department of Energy (DOE), U.S.A.

Kanda, Masato, Deputy Vice-Minister for Policy Planning and Coordination, Ministry of Finance, Japan; Chair, Corporate Governance Committee, OECD

Wilsdon, James, Professor of Research Policy, The University of Sheffield, U.K.; Vice-Chair, International Network for Government Science Advice (INGSA), New Zealand

Chair: Paquet, Jean-Eric

Opening Remarks

The chair opened the session and underlined necessity of research and innovation in providing solutions for policymakers, societies and citizens in dealing with climate, economic and social transitions which are complex, involve trade-offs, and are cross-sectoral in nature. Science and research as a policy and methodological tool, dealing with long time frames, enables social innovation and additional knowledge to allow for evidence based policy-making.

The panel began by discussing the positive and negative roles of science and technology, especially playing a part in undesirable aspects of

human history, through war and enabling personal greed. Problems persist from powerful actors which challenge free market principles and scientific methods. While the scientific community understands past misadventures, it often acts with disregard, which degrades trust in science.

Then, focus was brought on the importance of dialogue between science, governments, and the public for transparency, openness, integrity, and science and digital literacy to promote interest in science and detract from skepticism of science. In this regard, advisory councils on AI can ensure that the technology benefits all its stakeholders through public engagement and civil society dialogue.

The panel highlighted the role of direct impact of universities in public debate, through education of the populace, research activities, and their role as advisors which help to solidify public trust. The public are interested in global challenges, and universities can interact with them directly through discussions and debates.

The issue of digital globalization and its effects worldwide was raised, concerning division, distrust, misinterpretation and misuse of data, and sustainability of the global environment. A possible solution is that STI can contribute to achieving the SDGs through solid frameworks for all stakeholders. Furthermore, universities can play a vital role encouraging cooperation with industry, and developing the next generation of human resources.

A further "shadow" to Science in Society was brought up concerning solutions to polarization of society. Polarization necessitates the inclusion of science-based policy to avoid misinterpretation or misuse of data. Facts which challenge prior held values are unlikely to be accepted by the public or policymakers and need decoupling to build trust.

Another matter discussed by the panel was the impact of rapidly evolving technologies that can supersede existing programs and prompt us to realign our efforts accordingly. Risks such as cyber security and automation, trust in the internet as well as transformations in energy technology, reveal issues of cost and incompatibility with current infrastructure. Consequently, policy decision-making will benefit from technical experts directly involved in the process.

Adopting a clear vision in policymaking is of crucial need so as to allow for better responses to the challenges of weapons of mass destruction, AI, cyber security, and polarization on social media. Interaction and well defined roles between academia, governments and markets should be encouraged to realize disruptive innovation.

The panel summarized the main characteristics of the topic as openness, integrity, scientific ethics, capacity building. Furthermore, a solution could be training scientists and policymakers in cross sectoral dialogue. International networks for government science advice, can lead to better sharing of data between research institutes, through "research on research."

Discussion

A group discussion on the aforementioned topics was held. The participants noted that there are barriers to knowledge sharing, and a lack of mobility between policy, academics, scientists and non-scientists, as well as scarce intergenerational dialogue.

It is also vital to identify the correct procedure for dealing with policymakers, which is especially relevant when scientific advice is ignored. Indeed policymakers have issues translating advice into the policy world, as well as translating science well to the public to gain trust and understanding.
The participants also discussed trust in society and strategies to restore this trust. Scientific trust is founded on expertise and authority, which can be expanded through open science

and wider communication with the public, while reflecting the issues of demographics within societal groups.

A further issue concerned the difficulty that the public have in identifying scientifically sound policy. To counteract this, scientists should consider their role as public experts, while balancing their research responsibilities, and the role of chief science relations officer that can be prone to identify the intention behind research cooperation.

The discussion spread to the topic of utilizing wider networks with a particular highlight to the current nature of fragmentation and polarization in society, which is not being combatted effectively through traditional media outlets in the wake of online social media.

The participants argued how to make the scientific world and the political world better suited to understand each other and how to handle the lack of proper training of students in the wider policymaking world.

S&T and Society
Innovation Ecosystem

[Chair]

Kobayashi, Yoshimitsu, Chairman, Mitsubishi Chemical Holdings Corporation, Japan

[Speakers]

Cheong, Clara Yujing, Head (Admin & Scientific Affairs), Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore [Future Leader 2018]

Gutfreund, Hanoch, Executive Committee Chairperson, Israel Science Foundation; Professor Emeritus, Physics, The Hebrew University of Jerusalem, Israel

Lee, Chih-Kung, Chairman, Industrial Technology Research Institute (ITRI) and Institute for Information Industry (III); Professor, Institute of Applied Mechanics, National Taiwan University, Taiwan

Raven, Tony, Chief Executive, Cambridge Enterprise, Cambridge University, U.K.

Tschinkel, Yuri, Director, Mathematics and Physical Science, Simons Foundation; Professor of Mathematics, Courant Institute of Mathematical Sciences, New York University, U.S.A.

Ueyama, Takahiro, Executive Member, Council for Science, Technology and Innovation, Cabinet Office (CAO), Japan

Chair: Kobayashi, Yoshimitsu

Opening Remarks

The chair began the session and stated that innovation ecosystems are an engine for growth enabled by science and technology. Next-generation technologies, such as quantum computing and AI, will bring the tides of change to innovation ecosystems. There are diverse forms of innovation ecosystems, with regard to culture and location, however, these innovation hubs are fortunately also characterized by universal elements.

The speakers started by addressing the roles of boundaries, environment, and audience in shaping innovation. Controlling innovation

within certain boundaries is fundamental for success. Proper preparation for effective innovation is vital for the acquisition of skills, and to make good use of funding. The priorities for innovation should be broad and less definitive, as expectations from other stakeholders could affect outcomes.

Then, the speakers spoke on continuous innovation which can promote the well-being of mankind, through reform of the approaches of academia, such as the training of students and faculty in the methods of innovation. Academia, government, society, and public are the stakeholders which are vital in balance in a culture of innovation, and for the development of this culture.

The issue of linking overall ecosystems, and government funding, from industry to academia through public-private partnership was broached. Blue sky research is important for innovation, however, gaps between industry, academia and innovation hubs need to be bridged, the speed of these interconnections must be quickened, and increases must be made in the funding of basic industrial research.

Following this, the speakers discussed the origin of university-based ecosystems. Innovation ecosystems need not be of a large size and often have humble beginnings. Furthermore, the method for success must be tailored to local concepts and culture. The speakers also mentioned that research universities provide a flow of ideas and graduates who indeed help foster growth for a local ecosystem.

The speakers highlighted the elements necessary in developing an innovation ecosystem. An apt location in a major city nearby universities is an important element in the development of the ecosystem. Also, innovation ecosystems need good communication with the public, joint funding processes, and long-term collaborative research between fields.

Another issue discussed by the speakers was the innovative policies which are necessary for transformative innovation. Innovation ecosystems are complex and interconnected in nature, therefore the connections between actors must be considered in policy. Universities in the role of a knowledge industry are critical, whereas caution must be heeded in single-minded policy targets.

Discussion

A group discussion on the aforementioned topics was held. The participants highlighted that innovation needs action from all stakeholders for further progress, and for appropriate outcomes which are inclusive of all. National issues such as an ageing society must be reflected in policy plans, and innovation must address these long-term issues.

The participants also discussed the framework conditions for successful ecosystems, including intellectual property rights, venture capital and angels, and good governance. There is also a need for quick decisions and agility in innovation hubs. The mindset of innovation should be developed in universities.

The participants also stated that innovations which do not lead to direct commercial benefit are nevertheless important for the well-being of citizens, in areas such as health care, therefore basic research funding is necessary, as well as accountability of research and efforts to apply research. This is important because research should identify problems and not be discipline based. A world class research institute which is easily accessible,

as well as cooperation with universities and local governments are also vital elements of innovation hubs.

The participants discussed the inherent contradictions in the discussions on innovative ecosystems. A certain disregard for innovation ecosystems from local government leads to an atmosphere of freedom, and a free migration of people between large companies and startups. Governments who would like to design and create ecosystems while being protected from risk, are at odds with the organic and chaotic nature of the origin of ecosystems.

The discussion moved to the topic of setting up the necessary universities in an orientation which enables innovation. The connections between groups is far more important in this organic ecosystem, and thus from a policy perspective, key performance indicators must be broad in order to not stifle innovation, as some elements are not easily quantified nor consistently lead to success.

Moreover, the discussion focused on the limitations of large corporations, due to cultural differences present in these corporations because of their size. The culture of failure that large corporations have compared to startups is also of note.

S&T and Society
Information and Communication in the Digitalized Society

[Chair]

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

[Speakers]

Fowler, Nick, Chief Academic Officer, Elsevier, Netherlands
Hariri, Mehrdad, CEO & President, Canadian Science Policy Centre, Canada
Moloney, Michael H., Chief Executive Officer, American Institute of Physics (AIP), U.S.A.
Sweeney, David, Executive Chair, Research England, U.K.
Yamagiwa, Juichi, President, Kyoto University; President, Science Council of Japan (SCJ), Japan
Yokohama, Shinichi, Chief Information Security Officer (CISO), Nippon Telegraph and Telephone Corporation (NTT), Japan

Opening Remarks

The chair started the session and remarked on the significant changes in internet technologies, technologies which started democratic in nature. The equitable dream of early internet pioneers now confronts the reality of the use of the web for the sharing of misinformation, committing fraud, and manipulating foreign elections. The prior status quo of permanent non-changing information is now radically different, where presently information is ever-changing and truth is under a fundamental challenge.

Chair: Mazur, Eric

The system of scholarly communication was compared with broader online communication in society to try to identify the Parameters of Digital Literacy. Those parameters include: First, the need to be literate about who the author is, as well as about the content that s/he generates. Second,

the power of peer-review, of knowing who is facilitating and doing the reviewing, and according to what value system: is it the pursuit of truth, of fame, of data—or of advertising-based revenues, of votes, or of something else? Third, how knowledge of the system operator's values influence the reader's interpretation of the content and metrics about it that is being presented to them. And finally, how platform users "read", interpret and respond to what AI and machine learning may be serving them, whether for positive or negative effects.

Then, the speakers highlighted the downside to mass participation of the public in media technologies, drawing a distinction between parallel truths, and misinformation, and intentionally sharing falsehoods for nefarious purposes. Policymaking to protect openness and truth is far behind the rate of technological change, and a framework to protect the truth online must be adopted. How to address the challenge should be based on 3 principles: inclusion and multi sectoral efforts, and need a paradigm shift in policy making by building an open horizontal and digitalized government.

The speakers discussed that changes in broadcast news have led to more opinion being presented and less reporting of facts being done, which in turn has contributed to the current spread of misinformation. The lack of ability to differentiate between facts, news, and opinion has resulted in a discounting of expertise. One countermeasure would be to have digital literacy to be included early in education. Adequate partnership, and well-written translation of scientific data should also be pursued.

The issue was raised that science and technology, and advancements in AI, have only improved humankind's intelligence, but ignored human consciousness, relationships, and the ability to predict trends, as well as understand cultural differences. To effectively prepare for the future, we must also think about what human beings and society actually are, and engage in interdisciplinary and cross-disciplinary dialogues, and information analysis.

Following this, the speakers spoke of problems in digital literacy which have stemmed from the misuse of scientific methodologies. The scientific community needs to engage with the public to ensure methodologies are not used to perpetuate prejudices and to respond to claims of elitism. Also, the peer review system should be maintained as a tool for spreading truth, although it needs reform and improvement.

Another matter discussed by the speakers was the necessity of the involvement of hackers in the improvement of cyber security in communications. Bad actors use weakness in cyber security for the distortion of data, commercial gain, and political gain. Further improvements in cyber security can be founded in adopting a risk-based approach to protection of communications and the involvement of multiple stakeholders.

Discussion

Following this, a group discussion was held. The participants stated that solutions to the spread of misinformation may be regulatory or technological in nature. The individual behaviors of searching for appropriate evidence, or a tendency to confirm one's beliefs are both possible in the digital sphere and regulation or technology could seek to nudge this towards the former. Government regulation protecting against misinformation may be received as overly authoritarian and akin to censorship. The participants questioned whether scientific evidence was powerful enough in the face of stories which may have more impact for the public.

The participants also discussed the nature of objective truth, as it concerns distinguishing between fake and real images, and distinguishing truth from fiction. Furthermore, the reproducibility crisis also poses an issue to trust in truth in the digital era. The participants also mentioned that modern digital life gives easier access to information, but also creates an information overflow for users.

A further issue that the participants spoke on was the current post-truth society which has been influenced by relativism, and further divisions which are occurring in society in the face of widening connectivity.

The discussion spread to the topic of gaining the trust of society and reducing disinformation. Increasing the sense of personal responsibility for one's digital hygiene is a possible solution to this. Another possible solution to this lack of hygiene could be training in logic or the ability to read political bias. In addition, the participants stated that authoritative sources are needed on the web for news and facts, especially as investigative journalism is being discontinued by major media outlets.

The discussion also highlighted that the ever-changing web due to data-driven websites results in a lack of an authoritative archive, and allows for the ability for statements with political ramifications to be redacted, while the effects of said statements continue to spread.

ICT
IoT and Cloud in Society

[Chair]
Riza, M.Sc, Hammam, Chairman, Agency for the Assessment and Application of Technology (BPPT); Indonesia

[Speakers]
Wohn, Kwangyun, Chairperson, National Research Council of Science and Technology (NST), Korea
Doi, Miwako, Auditor, National Institute of Information and Communications Technology (NICT); Executive Director, Nara Institute of Science and Technology (NAIST), Japan
Hara, Hirotaka CEO and Representative Director, FUJITSU LABORATORIES LTD., Japan
Mencer, Oskar, CEO, Maxeler Technologies, U.K.
Shimada, Taro, Corporate Vice President and Chief Digital Officer, Toshiba Corporation, Japan
Stephen, Craig, Senior Vice President, Research & Development, Oracle Corporation, U.S.A.

Opening Remarks

Chair: Riza, M.Sc, Hammam

The chair opened the session noting that IoT is rapidly becoming mainstream as people increasingly introduce start devices into their homes, with some estimates that by 2020 there will be more than 21 billion connected devices, covering areas including smart health, autonomous vehicles, drones, smart glass, and many others.

The session speakers were then invited to offer comments. Discussions began with the introduction of a research project considering the potential use of IoT to manage infrastructure hidden underground, such as power lines, sewerage systems, etc., and ensure their safety, such as through detection of sinkholes that can cause damage to infrastructure. More broadly, the expectation is that almost all objects will

become intelligent agents, with some degree of sensing, reasoning, communication, and potentially also physical abilities. The issue was also raised of who will design the individual culture of IoT environment tailored to the individual's cultural choices and expectations, and the related implications.

The discussion then shifted to the issue of the proliferation of sensors that form the infrastructure for Society 5.0 or the Smart Society Initiative, and the related data and analysis. It was noted that the data should be used to achieve the goal of the user, but there are issues with manufacturers collecting data and using systems for their own goals and the goals of third parties. However, there are also enormous potential benefits that can be obtained by this kind of real-time data collection and processing such as the ability to react to incidents and improve predictions related to natural disasters.

The speakers noted that new digital technologies are expected to play an important role in society as we face many complex challenges. The concept of human-centric intelligent society was introduced, which aims to empower society through digital technology, which is closely related to achievement of the SDGs. Examples given included predicting water levels based on small amounts of past data on rainfall and water levels, and stream data processing technology for real-time optimization of transport movements across entire cities. It was noted that for IoT to permeate society an ecosystem must be formed with cooperation between business, academia, local government, and national government.

Next, the speakers discussed the importance of low size and weight in IoT devices for portability, which necessitates more efficient designs to minimize the power supply requirements. The speakers also highlighted the challenges regarding where the responsibility and liability lies for actions taken and choices made by IoT systems, in the event of undesired outcomes, as they begin to play a greater role in our lives. It was noted that these could be thought of as new unintended conflicts that are created in attempting to solve existing problems and conflicts.

The speakers also discussed the challenging business environment surrounding IoT, where businesses are finding it difficult to generate profit from IoT. This is due to a balance of requirements and issues, such as affordability, agility, and finally availability, which includes interconnectivity and compatibility between disparate devices. One proposed approach to address these issues is to use microservices, which are small building blocks that can be combined to create different systems and services.

The speakers then considered that technology should not be the limitation for IoT devices, as the arrival of 5G technology allows for high speed data transfer, but that most of the issues are likely to be around the issues of privacy and security. However, we must understand the challenge is really around transparency as companies naturally want to monetize the large investments that they are making to acquire data, and whether individuals should be paid for their personal data by infrastructure providers or tech companies that resell that data. It was noted that while privacy regulations give some protections, they do not consider the forces that drive the markets. It was highlighted that there are many difficult choices that policy-makers will need to consider requiring an active exchange of ideas in fora like the STS *forum*.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon academic and industrial ideas for the application of IoT, the privacy issues raised related to the use and processing of individual data in creating a commercial system, and the need to engage with local communities to gain acceptance. There was also discussion on the use of IoT in addressing SDGs and identifying areas of optimization toward achieving the SDGs that can inform IoT system design.

The participants also discussed the use of decision support systems in clinical practice, and the issues of trusting recommendations from machine learning algorithms when the basis for the decisions is not provided. It was also noted that these systems often do not consider important background knowledge and personal preferences, and that there are also wider issues concerning the data quality.

The discussions also touched on the need for legal structures to be put in place to protect citizens from IoT technologies, as there is little protection currently in place in most countries around the world. There was consideration of the qualitative differences of the societal changes compared to the previous industrial revolutions, including the impact on jobs and retraining due to relative levels of complexity.

The participants pointed out the stark differences between IoT use in the industrial environment compared to the public/social environment, which is much more complex due to the tradeoffs that need to be made over privacy, informed consent, ownership and control, and costs.

There was also discussion on trust, and the potential gaps between intent and reality. An example given was the case of Tesla, where customer data could unwittingly be revealed to a prior owner when a car is resold. The participants also highlighted the difficult issue for governments in struggling to keep pace in terms of regulation of technology, and the potential negative impacts of regulating too heavily in terms of stifling innovation.

Finally, it was noted that although the widespread use of IoT generates large amounts of data, the focus should be on ensuring the appropriate use of that data to create an inclusive society.

ICT
Cybersecurity and Connected Society

[Chair]

Copan, Walter G., Director, National Institute of Standards and Technology (NIST), U.S.A.

[Speakers]

Misumi, Ikuo, Deputy Director-General for Cybersecurity and Information Technology, Ministry of Economy, Trade and Industry (METI), Japan

Thompson, Herbert Hugh, Chief Technology Officer, Symantec Corporation, U.S.A.

Miyaji, Atsuko, Professor, Graduate School of Engineering, Osaka University; Professor, School of Information Science, Japan Advanced Institute of Science and Technology (JAIST), Japan

Chaos, David, Global Chief Information Officer (CIO), Technology and Operations, Santander Group, Spain

Spiropulu, Maria, Shang-Yi Ch'en Professor of Physics, Division of Physics, Mathematics and Astronomy, California Institute of Technology (CALTECH), U.S.A.

Hampapur, Binod, Executive Vice President & Global Head, Talent & Technology Operations and Quality, Infosys Limited, India

Laidmets, Mart, Vice Minister, Ministry of Education and Research of the Republic of Estonia, Estonia

Chair: Copan, Walter G.

Opening Remarks

The chair opened the session noting that cybersecurity is at the intersection of policies, people, and technology, and that the technology advances outpace policies. The interconnected nature of emerging technologies creates huge value for society, but at the same time makes the security landscape extremely difficult. The challenges are best addressed through open, transparent collaboration. New attacks and attackers are emerging constantly, with new modes of attack including harder to detect botnets. The Cybersecurity Framework is an aspirational approach to help organizations to improve their systems and manage the risks they

face. As 5G is deployed wireless technology will become the primary way that devices are connected, bringing associated additional risks.

The session speakers were then invited to offer comments. Discussions began by noting the importance of public-private partnerships (PPP), as most of the development and use of the Internet has been led by private sector companies. Two aspects where the private sector is expected to play an important role are prevention and incident response. The Japanese Government has developed the Cybersecurity Physical Security Framework to help address challenges in IoT systems. The speakers noted that PPP is also essential to respond effectively to cybersecurity incidents. Many companies fear sharing information due to the potential for negative impacts, and therefore mechanisms for confidential information sharing have been created. In doing so, building trust among stakeholders is essential.

The speakers then highlighted how attacks today are more customized to individuals, using approaches that trick them into making a choice that leads to their security being compromised. It was also pointed out that most individuals have a huge information disadvantage with users' vulnerabilities being exploited, and that "trusted" third parties and supply chains may not be neutral.

The speakers then touched upon the privacy issues related to use of IoT devices, where it may not be clear where the data is being collected, how secure that data is, and how it will be used.

The speakers also pointed out that in banking much more is spent in cybersecurity than in physical security, noting that the cybersecurity area is international by its nature, and therefore requires international legal frameworks and cooperation. There are also challenges around ensuring sufficient knowledge, training and awareness both for executives and more generally. The question was also raised of whether quantum computing will solve cybersecurity issues or create new problems.

The speakers then discussed how anomaly detection can be used to detect fraud based on a variety of variables, and how with sufficient data and pattern analysis this can also become predictive. It was also noted that breaches are not the only risk, with denial of service also constituting a major risk. There was also a discussion of zero-trust approaches to security, quantum communication techniques, and post-quantum cryptography techniques.

The speakers touched upon the difficulties of maintaining awareness of cybersecurity risks, due to the ever-increasing range of attack vectors. The case of a casino which was hacked through an internet-connected temperature sensor in a fish tank was given as an example of how unexpected routes may be used to gain entry to systems.

The speakers discussed the case of Estonia where almost all government services can be conducted online 24/7. Various technical measures are taken to ensure the security of the system, but one of the greatest areas of vulnerability is the citizens themselves, and therefore efforts are made in education and awareness of cyber-hygiene.

The group then further discussed the popularity of the concept of zero-trust, noting that even when the identity of a remote entity can be confirmed there are challenges around ensuring that the remote entity has not been influenced by a third party in some way. An example was given of voice call-based attacks which used machine learning systems to emulate the voice of the CEO of the organization to request an immediate wire transfer.

The group also discussed the evolution of cryptographic algorithms, the difficulties of ensuring that these are implemented into systems correctly, and how security can be layered on top of existing systems to allow for replaceability of the security components.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon legislation in certain sectors such as transport being driven by safety and accidents, and the risks around intentional interference with machine vision systems. One point raised by the group was that in many cases technical solutions exist but that it can be difficult to get people using those solutions if they reduce convenience.

The participants also discussed the rising costs of cybersecurity solutions, and asked at what point the costs will become so high that it will make sense to redesign entire systems from the ground up to enhance the inherent security.

The group then touched upon the conflict between usability and security, and how good preparation can minimize the effects of any attack, but noted that the costs of prevention are nevertheless escalating.

The group also mentioned the security problems created by backdoors introduced into systems for reasons of national security, and the need for continuous education as security is a continuous process. Finally, the possibility was raised of performing database operations directly upon encrypted data to avoid having to decrypt data.

ICT
Utilization of Big Data

[Chair]

Flandrin, Patrick, Vice President, French Academy of Sciences; Director of Research, Physics Laboratory, The French National Centre for Scientific Research (CNRS), France

[Speakers]

Leptin, Maria, Director, European Molecular Biology Organization (EMBO); Professor, Institute for Genetics, University of Cologne, Germany

Hanahoe, Hilary, Secretary General, Research Data Alliance (RDA), U.K.

Hoang, Tien Nam, Chairman, Board of Directors, FPT Software Co., Ltd., Vietnam

Peitsch, Manuel, Chief Scientific Officer, Philip Morris Products S.A., Switzerland

Ataka, Kazuto, Professor, Faculty of Environment and Information Studies, Keio University; Chief Strategy Officer, Yahoo Japan Corporation, Japan

Opening Remarks

The chair opened the session by noting that big data is no longer just about volume, velocity, and variety, but also now value and veracity. The chair posed questions for the group including "Is bigger really better?", "How can we prevent biases?", "What kind of protections should be in place for privacy, etc.?", and "How do we make processing of big data more sustainable in terms of energy consumption?"

Chair: Flandrin, Patrick

The session speakers were then invited to offer comments. The speakers first discussed how to allow access to a broader range of datasets in parallel rather than single large datasets, peer review methods and how to ensure quality and reliability of data, and also how to prevent our personal health data from being used against us.

The speakers then highlighted the value of sharing of big data in areas such as

agriculture, which cannot be achieved without standards for exchange. The question was raised of whether there is scope for large-scale international public-private agreements for sharing and reuse of publicly-funded research data, while at the same time safeguarding the interests of data providers, and providing benefits to both the public and private sector while also contributing to society. The importance of interoperable data was also highlighted for accelerating the achievement of the SDGs based on the related monitoring targets.

The speakers then discussed how 90% of the data in the world was generated in the past two years, and how the pace of data generation continues to accelerate with the proliferation of IoT devices. It was also noted that more than 80% of data is unstructured, requiring AI techniques to process it. The group also pointed out that it is now possible through public data to generate a more complete profile of a person than their loved ones could. It was also noted that it is possible to extend this to predict what people will want or need at a future point in time.

The speakers discussed the challenge of developing products that reduce the health risks and impacts of tobacco by eliminating the combustion aspect. It was noted that this requires long-term research, as manifestation of smoking-related diseases takes many years. As an alternative approach, the concept of systems toxicology has been developed out of the basic principles of systems biology, based on big data to generate biological effect potentials. Key challenges beyond data privacy are data mobility, data quality and traceability, understanding how treatment perturbs a biological mechanism, and verification of scientific conclusions. Data reuse is also critical, to enable verification and advancement, which can be addressed by using a platform that adheres to the FAIR principles (findable, accessible, interoperable, and reusable).

The speakers mentioned the value of long-tailed data to generate functional services including search and proper suggestions/recommendation on many data-driven services. The speakers then discussed how value is created from analysis of connected customer data and preferences, and how enhanced privacy regulations could have a drastic impact on the ability to provide free services. It was noted that regulations such as GDPR may also place a greater relative burden on small players and startups, which could stifle innovation and benefit the big players. It was also noted that as computational demands increase there is also potential for large energy and environmental impacts, so aspects of efficiency must be addressed.

Based on the comments of the speakers, the chair asked whether there could be a concept of fair data, that is useful, green, not redundant, and not biased, for example. It was pointed out that the concept of personalized medicine relies on big data but provides tremendous value and benefit, so huge datasets certainly do provide societal benefit.

Discussion

Following the opening remarks, a group discussion was held. The participants first discussed energy management for data storage, policies and guidelines for government data storage, and how to ensure data quality.

The group also discussed the consequences of loss of public faith as a result of data breaches, aspects of trust issues on all sides, the need for a code of conduct for data scientists, and how to ensure that there is transparency and value for all in any global framework.

The discussion also touched upon how individuals are trading privacy for convenience, raising the question of how much of this convenience is really needed. The discussion also highlighted the need for accountability on how data is used.
The participants discussed the idea that datasets should be open and anonymized, but noted that this raises the question of how to ensure that data is sufficiently anonymized.

There was also discussion around how crowd sourcing can provide a sort of peer review, as replication by others is the best form of verification of results.

The group also noted that data is often unstructured or shared in a form that creates problems for reuse. It was also noted that the volume of data and lack of standardization can make meaningful analysis difficult. In addition, it was noted that data governance is important to prevent unintended consequences.

The group also considered whether the cost of data would accentuate inequality, and considered aspects of ownership and reproducibility, training for handling of data, and the concentration of talented human resources in the private sector.

Social Infrastructure
Advanced Transportation Systems

[Chair]
Chen, Wenchi, Chairman and President, VIA Technologies, Inc., Taiwan

[Speakers]
Kikuchi, Noboru, President, Toyota Central R&D Labs., Inc., Japan; Roger L. McCarthy Professor Emeritus of Mechanical Engineering, College of Engineering, University of Michigan, U.S.A.
McIntosh, Stephen, Group Executive, Growth & Innovation, Rio Tinto, Australia
Nikiforov, Nikolay, Chairman of the Board, Diginavis; Member of the Supervisory Board, Innopolis University, Russia
Romanowski, Michael, Director of the Policy and Innovation Division, Aircraft Certification Service, Federal Aviation Administration, U.S.A.
Tabet, Said, Distinguished Engineer and Chief Architect, Dell EMC, U.S.A.
Tremblay, Sébastien, Director, Joint Research Unit in Urban Sciences - Université Laval, Canada
Ohuchi, Satoshi, Deputy Director-General, Manufacturing Industries Bureau, Ministry of Economy, Trade and Industry (METI), Japan

Opening Remarks

Chair: Chen, Wenchi

The chair opened the concurrent session by commenting that the availability of transportation together with automation technology and new business models is expanding by road, rail, and air. To add to that, with trends of aging societies, the chair posed a question to the participants about what the best path forward for advanced transportation systems would be.

The speakers presented the issues of parking and the time that private vehicles are not in operation. Through research, artificial intelligence (AI) technologies increased the success rate of autonomous vehicles (AVs) and individuals in the area believe that

autonomous driving could be utilized along with other technologies to transport people and goods.

Next, the speakers discussed the AVs utilized in Australian ore mining. Not only were trucks automated, but the longest, heaviest rails were automated. These rails do not operate in a closed environment and the approval of these systems proved to be a challenging endeavor. The regulation piece of utilizing this technology remains to be the most challenging element.

Discussion then took place around creating a software platform to control automation both on land and in the air. This software platform can prove to be a comfortable layer between the government, stakeholders, society, and all that are involved in or influenced by AVs. In Russia, approval was granted for an AV experiment which could shine light on how AVs should be controlled.

Following, the speakers touched on urban air mobility and regulatory issues that remain challenges for enhancing automation in aircraft. Looking at unmanned aircraft for other services, such as medical and delivery, has provided insight into certification of these technologies. The community acceptance of unpiloted vehicles is one of the biggest hurdles, especially due to safety.

Another topic discussed was the issue around growth, sustainability, and how technology in society can come together for the benefit of human-kind. As we are going through a digital transformation, we are seeing challenges in a data-driven world. Therefore, technology must be innovated, for example, into AVs which are multi-use and have multiple owners.

The speakers explained that cities spend a lot of resources making transportation more fluid and a key challenge is for cities to offer transportation that is enhanced in all aspects. Adaptiveness and connectedness are factors that need to be involved to make this enhancement possible. Implementing this within cities remains to be the main challenge.

Finally, the speakers introduced Japan's challenge around transportation which is based on the aging society. In rural areas, access and availability of transportation for the elderly is a social issue. The utilization of the Internet of Things (IoT) and AVs could provide some resolution, and ministries in Japan have started mobility programs by implementing new transportation services.

Discussion

Following the opening remarks, a group discussion was held. The participants discussed why now would be a good time to push for AVs because there are many benefits, however, there are many roadblocks that need to be addressed. Also, liability of these vehicles was touched upon which proves to be a sensitive subject. There should be a shift from car companies to mobility companies in order to create fluidity between modes of transportation.

The participants then discussed specific safety cases especially with regards to fatal accidents involving AVs. Over-reliance of humans on AV systems proves to be a safety issue. Regarding unemployment, AVs have taken people out of the driver's seat. Therefore, programs to train, upskill, and reemploy these individuals should be developed.

Discussions were then engaged around data ownership. Ways must be developed to send relevant data to the cloud instead of sending all data to the cloud. Also, software assurance needs to be addressed and whether the owners would be able to modify the software. The challenge of how to handle an emergency situation must be resolved.

Following, the participants put focus on mobility as a service. Also, the role of governments depend on each country, so each one needs to address the issues in their own ways. Within

countries, there are challenges around what can be done in rural versus urban situations. Regarding safety, humans are the questionable factor. As a result, liability and responsibility becomes an uncertainty. Decarbonization cannot be incentivized without infrastructure, which is expensive and challenging to put into place.

Finally, the participants touched on the seamless connectivity of transportation. Malaysia has recently begun a program of semi-autonomous vehicle implementation. In India, there is a lot of reliance on driving as employment, so implementing AVs is not widely socially accepted.

Social Infrastructure
Population and Urbanization

[Chair]

Catlett, Charles, Senior Computer Scientist, Argonne National Laboratory; Senior Fellow and Center Director, Mansueto Institute for Urban Dynamics, University of Chicago, U.S.A.

[Speakers]

Yamanaka, Akiko, Special Adviser to the President, Economic Research Institute for ASEAN and East Asia (ERIA); former Vice Minister, Ministry of Foreign Affairs, Japan

Dakora, Felix Dapare, President, African Academy of Sciences (AAS), Kenya

Blanco Mendoza, Herminio, President, IQOM, Inteligencia Comercial; President, IQOM Strategic Advisors, Mexico

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

Pikalo, Jernej, Deputy Prime Minister and Minister, Ministry of Education, Science and Sport of Republic of Slovenia; Professor, Centre for Political Theory, Faculty of Social Sciences, University of Ljubljana, Slovenia

Opening Remarks

Chair: Catlett, Charles

The chair started the concurrent session by making introductory remarks. There has been an unprecedented migration into urban areas. The way cities are set up now is not suitable for this increase in urban migration. New tools and data are arising which will contribute to urban optimization. Today, various projects and experiments are underway in order to better understand how systems interact and to analyze the performance of urban areas. The tools that are starting to become available give us a realistic expectation that cities can be designed with AI-based optimization.

The speakers first discussed ensuring the resilience of society through science and technology. In terms of Japan, legal

restrictions have resulted in greater impacts of natural disasters. Another issue proved to be raising awareness around disaster effects, attention to warnings, and complacency. Infrastructure, science, and technology are necessary in order to mitigate and alleviate the effects of natural disasters. Finally regarding Japan, keeping healthy and having work-life balance using science, medicine, and technology in urban areas has been at the forefront of people's minds.

Following, focus was put on the increasing populations in cities in Africa. Many cities in Africa do not have the resources to accommodate urban migration. The implementation of technology, such as robotics, has no effect on this issue, so other solutions must be developed. Food security is another major challenge in Africa. Farming areas have been urbanized and developed because there are no regulations around designated agricultural land. As a result of urban migration in Africa, un-governable areas have sprung up causing harmful impacts on society due to the lack of resources to govern them.

Considering urban economics, the speakers touched upon the growth of large cities in Mexico. An urban economic model which the speakers discussed states that the size of cities depends on what cities offer in terms of the preferences of citizens, but in reality, this is not the case. Cities that have a large population tend to grow faster because they are more attractive in some dimensions, such as in productivity, infrastructure, and quality of life. Water in Mexico City remains an issue because the city has to transport it in which is costly.

The speakers moved on to discuss disaster reduction measures. The three most devastating natural disasters are extreme weather, floods, and earthquakes which are closely related to rapid population increase and urbanization. As a result, it is vital to incorporate disaster risk reduction into the Sustainable Development Goals (SDGs). Information gathering and dissemination will be the key to improving resilience and improve disaster risk reduction.

Finally, the speakers spoke on similar issues in Slovenia that were discussed earlier about other countries. Regarding urbanization, it is a global trend that people are migrating to seek better lives. As individuals move into the most urban areas of Slovenia, the school system is overburdened by the influx of children. Also, intellectual migrants, not only labor migrants, integrating into society provides additional strain on urban schools. As a result, sustainability of the urban areas is threatened and the public school network is strained as fewer children attend schools in rural areas.

Discussion

After the opening remarks concluded, the participants held group discussions. In the group discussions, the participants discussed various topics around population and urbanization including planned and unplanned urbanization resulting in two types of polarization within cities. Also, the topic of the future of politics came up and the necessity to change the mindset in that area.

The participants then highlighted issues due to rapid population increase and urbanization. Disaster risk reduction is not a high priority considering the more serious issues that cities face. Natural disasters are caused by three factors including hazards, vulnerabilities, and exposure. As the population increases, vulnerability and exposure increase. Large cities that are growing are at a higher risk of natural disasters. Also, climate change causes increases in the hazards themselves. Actions or solutions to face increasing risks from disasters need to be addressed. In developing countries, the solution would be to prioritize risk reduction. For developed countries, the solution would be to change lifestyles, including utilizing science and technology to help people live outside of large cities by enhancing connectivity.

Finally, the participants exchanged ideas around the differences between small and large cities. Implementation of ideas in smaller cities could act as a test bed for larger cities.

Once people use services like education in urban areas, they tend to stay in those urban areas which is one of the sources of further urbanization. Polycentric policies and direct investments into other cities and other areas of the countries, or planned urbanization, could alleviate these issues. Transportation was also addressed in terms of how it influences population and urbanization. Instead of reducing the burden on large cities, it actually increases the burden. In addition, the participants mentioned that underdeveloped areas of countries tend to be the sources of migration to urban areas.

Social Infrastructure
Agriculture, Food and Water Security

[Chair]

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

[Speakers]

Catley-Carlson, Margaret Y., former Chair, Global Water Partnership; World Economic Forum (WEF) Water Agenda Council; Suez Foresight Advisory Committee, Canada

Takeuchi, Kazuhiko, President, Institute for Global Environmental Strategies (IGES); Project Professor, Institute for Future Initiatives (IFI), The University of Tokyo, Japan

Gleick, Peter H., President Emeritus, Pacific Institute for Studies in Development, Environment and Security, U.S.A.

Sakai, Takako, Deputy CEO, Mikado Kyowa Seed Co. Ltd., Japan

Lim, Chuan Poh, Chairman of the Board, Singapore Food Agency (SFA), Singapore

Pearson, Simon, Professor, Agri-Food Technology, University of Lincoln, U.K.

Opening Remarks

Chair: El-Beltagy, Adel El Sayed Tawfik

The chair began the concurrent session by emphasizing the importance and the urgency to tackle the food production, consumption, and food waste issues in relation to water security. Optimizing water use efficiency and nutrient efficiency related to improving the adaptive capacity to cope with the impact of climate change on reduction of agriculture produce which may reach 50% by 2050. Population increase may reach 10 billion by 2050, which will further impact water and agriculture security. Using advanced tools of science and technology (precision, smart, e-agriculture, artificial intelligence (AI), synthetic biology, genetic engineering, nano-technology, etc.) requires a massive trans-formation in agriculture and food industry

systems (Agriculture 4.0). The new horizon needs intensive human capacity building policies, legislations, and public awareness, in order to manage this transformation. In this session, the participants needed to come to conclusions around gaps to be filled and innovative solutions to the global, regional, and local issues of agriculture, food, and water security.

First, the speakers considered the Himalayas and Hindu Kush and reported that particularly in the impact on the 10 rivers which provide food security and energy across Asia, climate change will have a major impact on Asian economies. In order to slow the melting of glaciers, a decrease in emissions and soot are solutions. In Asia, making irrigation more efficient, instead of taking up increasing amounts of groundwater requires collaboration with farmers' behavior and needs.

The speakers then turned to agroforestry being one way to reduce deforestation for agriculture. Planting crops among the forest, as the indigenous population does, such as in the Amazon, contributes to environmental conservation and food production, and diversifying to crops that use a low amount of water could be an action that produces results.

Following, the speakers added to the challenges faced in agriculture, food, and water security. It is possible to have enough food for the world's population in the future, but we need to figure out the best way to make that happen. Instead of producing more food, the population should eliminate food waste along the supply chain.

Focus was then put on the seed industry in agriculture. The market share has grown in the past 10 years, but the business situation is changing. Seed companies have started to tackle harder targets. Using AI or prediction farming technology could be a solution. For example, researchers and breeders have started to monitor the root system and surrounding soil condition by high-tech cameras and various sensing technologies. The combination of new technology and breeding could be a solution for development of an efficient water management system in agriculture. Also, vertical farming is becoming a trend in Asia, which can be a solution for countries with a dense population or tropical zone. Seed companies are doing a lot to select varieties which flourish in those changes of farming and environment.

The speakers moved on to talk about water and food security in Singapore. After gaining independence, Singapore was water poor and relied heavily on food import. Now, imported water is still significant, but the most important addition is NEWater. NEWater is essentially

drinking water recycled from used water such as sewage and sullage water from households and commercial premises. Regarding the food situation in Singapore, getting the community to grow their own vegetables is a plan for the future.

Finally, the speakers went over the notion of Agriculture 4.0 which is about digital technology, such as AI, machine learning, and drones, that can transform agriculture. How to get the whole world's farms up to Agriculture 4.0 is going to be the major challenge of the future along with the risk that unemployment will be driven up as people are replaced by robots. The speakers emphasized the critical importance of taking a "systems approach" to such a global challenge.

Discussion

Group discussions were held after the opening remarks from the speakers. In the discussions, the participants covered various crops which could benefit from enhanced farming; threats and risks such as typhoons and price increase; the importance of developing more seeds for drought resistant crops; and the fact that action must be taken locally.

The participants also discussed issues around the supply chain, highlighting there are bad actors damaging the system. Also, nutritional needs should be considered to determine

what to grow in local areas which match the local needs. In India, farmers are decreasing because it is considered to be a low-level job resulting in farmer suicides and farmers' children not wanting to continue the family business.

Touching on small-scale and localized issues, the participants discussed the importance of healthy food and the safety of food. In addition, energy consumption in food production and distribution needs to be considered and evaluated to determine if the present methods are harmful or beneficial. Common goals and understandings are around agriculture, food, and water security, but how to achieve the common goals is a challenge.

How to create the narrative to drive action was discussed, and in order to have people become aware is to enhance community engagement. Many effective solutions do not happen at the national level but at the local levels and hence continuous assessment of the impact on climate change of agro-ecology is highly required on the local level. Regarding crop insurance, seeds may be replaced in times of poor production seasons which provides a kind of insurance for the farmers.

To conclude, the participants deliberated on food production, consumption, distribution enhancement, and minimizing food losses. They stressed that linking farmers to the market and optimizing the mobility of the food chain (including long-term storage) will be beneficiary for the industry. Changing diets is required (i.e. minimizing meat consumption to optimize water use). Climate change is the biggest threat to water and food security. So, there is a need for enhancing coping and adaptive capacity, including introductions of new legislations, institutions, and public awareness. Continuous assessment of the impact of climate change on regional and local levels will impact the cropping pattern, and enhance water and food consumption. The implementation of SDG's, the Paris Agreement, and Sendai Framework in relation to the responsibilities on international, regional, and national levels were also discussed. Responsible action from the scientific community and society is highly needed.

Statement

1. The 16th Annual Meeting of the Science and Technology in Society *forum* took place from October 6 to 8, with the participation of more than 1,400 global leaders in science and technology, policymaking, business, and media from nearly 80 countries, regions, and international organizations.

2. The world is experiencing some negative changes. Not only world trade and security but also international collaboration in science and technology are facing major challenges as the multilateral global system is being called into question. At the same time, we are increasingly called upon to address the negative aspects of prevailing technologies and lifestyles, ranging from climate change and biodiversity loss to cybersecurity challenges to plastic debris in the oceans in order to ensure sustainable development for humankind and our planet earth. In this context, the role of the STS *forum*, where not only scientists but also policymakers, business executives, and other leaders gather and discuss the "lights and shadows" of science and technology as their own problems, continues to grow in importance and relevance.

3. This year we highlighted "Energy and Environment," which directly affects our lives. We discussed options for maintaining economic development, while controlling the shadows resulting from technological development. Other principal topics of our Annual Meeting included AI (artificial intelligence) and society, healthcare, financing of basic science, innovation, and international as well as academia, business, and government collaboration in science and technology.

Energy and Environment

4. The urgent necessity to address ever-increasing energy needs with minimum environmental impact requires transformative energy shifts from high- to low-carbon energy sources at unprecedented speed. In this context, nuclear energy remains a critical source for stable large-volume electricity generation, under strict conditions of safety, security, and non-proliferation. Investments must be made in advanced technologies for low-emission energy sources, reliable energy storage, massive electrification, and negative carbon emissions such as carbon capture and utilization. IT-based smart grids are essential for efficiently balancing sustainable energy supply and demand with minimum damage to the environment.

5. Climate change poses a threat to human lives, by causing extreme weather events such as hurricanes and forest fires, as well as extreme heat events. Erratic rainfall patterns cause floods, storms or droughts, which negatively affect water supply and agricultural production, impacting food security. We must continue to adapt to and mitigate climate change by utilizing scientific knowledge and data on Earth and the oceans collected through ocean monitoring and satellite observations. We also need to mobilize the tools of the biological and ICT revolutions to promote genetically modified plant breeding with desirable traits like salt and drought resistance and short growing season. This should be combined with precision farming, to increase efficiency of water use and minimize loss between farms and markets. Also, water and sanitation services should be available to all citizens.

Life Sciences and Healthcare

6. Rapid progress in life sciences has brought the promise of advanced and personalized medicine, such as gene therapy and regenerative medicine, along with the application of advanced analytics to biological data. That implies that discussion and guidelines on the ethics of applying these technologies to human beings must constantly be updated, especially as we seek new treatments for diseases for which current therapies are inadequate.

7. Supporting healthy aging is a primary issue, to improve quality of life and reduce the cost of social security and the burden on younger generations. Research is needed to assess if lifestyle changes and preventive and personalized medicine are to play an important role in keeping older people healthy.

8. Meanwhile, climate change brings the potential spread of infectious diseases through shifting climate zones. Sustained efforts are also needed to build an international system to help nations deliver good healthcare to all parts of the world, with the cooperation of WHO and other organizations.

Information-Driven Society

9. Through innovations such as robotics and machine-human interaction, AI, IoT (Internet of Things), and Big Data analytics, our societies are being changed at an unprecedented rate. While research and development to make our lives more pleasant and comfortable, safer and even smarter should continue, efforts should be made to address concerns that the progress of AI-driven society is having a negative impact, including job loss, on human society. In an ICT-centric society, cybersecurity is key to preserving individual freedom, respecting privacy, and guaranteeing a certain degree of anonymity. Social networking services must make stronger efforts to eradicate erroneous and inappropriate information from their platforms.

Basic Science and Innovation

10. Basic research has led to ground-breaking discoveries that have resulted in breakthrough technologies and expanded human horizons. The most important innovations have resulted from new scientific knowledge. Appropriate funding for basic curiosity-driven research is essential. Moving from scientific insight to usable technology requires collaboration among academia, government, and industry. Such collaboration is the basis for building a thriving innovation ecosystem, where scientific discoveries are translated into practical applications and industrial innovations are generated under the appropriate legal framework, including respect for intellectual property rights.

International Cooperation in Science and Technology

11. It is important to promote international science cooperation and collaboration to strengthen science and enhance science diplomacy to build bridges to developing nations.

Society and Science and Technology

12. Finally, if we are to effectively address climate change and the challenges that we face with growing populations and expanding economies, we must achieve considerable changes in our current energy mix and eliminate dependence on fossil fuels. Drastic action is needed that will require rapid political decision-making, new commercial strategies, and the development of new technologies. The STS *forum* is intended to provide the opportunity for dialogue between the actors to develop a consensus on how we can address the challenges of putting the world on a sustainable path for the future.

13. We look forward to meeting here again next year and have agreed to hold the 17th Annual Meeting of the STS *forum* in Kyoto from Sunday, October 4 to Tuesday, October 6, 2020.

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As of October 25, 2019

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