15th Annual Meeting

STS *forum* 2018

15th Anniversary STS *forum*

Summary

October 7, 8 and 9, 2018

Kyoto, Japan

Science and Technology in Society *forum*

Summary of STS *forum* 2018

STS *forum* 2018 - 15th Annual Meeting Program

October 6-9, 2018

Plenary Sessions | Concurrent Sessions | Invitation Only

October 6, 2018 (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 7, 2018 (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 Development [Main Hall]**				
	12:00-13:40	Lunch and Networking Time [Sakura]				
102	13:40-14:40	Plenary Session 102: **Lights and Shadows of Science and Technology [Main Hall]**				
	14:40-14:50	Break				
103	14:50-16:50	Energy **Renewable Energy and Power Grid [Room H]**	Life Sciences **Genome Editing [Room B-2]**	Engineering and Innovation **Industrial Innovation [Room C-2]**	Environment **Climate Change [Room G]**	
	16:50-17:20	Networking Time (Coffee Break)				
104	17:20-18:20	Plenary Session 104A: **Role of Science and Technology Education for Society [Room A]**				
105	18:20-21:00	Cocktails and Official Dinner [Event Hall]				

	12:00-13:00	Future Leaders Network [Sakura]			
	13:00-15:00	Dialogue between Future Leaders and Nobel Laureates [Sakura]			
	13:00-17:30	Regional Action on Climate Change (RACC10) [Room D]			
	12:30-15:30	7th Global Summit of Research Institute Leaders [Room C-2]			
	14:00-16:40	Symposium for Kyoto Citizens [Venue: Kyoto Chamber of Commerce and Industry]			

		12:00-13:00 CEO Lunch Meeting [Room 103]	12:00-13:30 CTO Meeting [Room E]	12:00-13:30 University Presidents' Lunch Meeting [Room A]	12:00-14:50 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 **Innovation Ecosystem [Room K]**	ICT **Artificial Intelligence (AI) and Society [Room B-1]**	Social Infrastructure **New Transportation Systems [Room J]**	
	Plenary Session 104B: **Science and Technology in Business and Finance [Main Hall]**				

October 8, 2018 (Monday)

	7:30	Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)							8:00-8:45
200	9:00-10:10	Plenary Session 200: **Society Changed by ICT [Main Hall]**							General Meeting
	10:10-10:30	Break							10:20-12:40
201	10:30-12:30	Energy **Net-Zero Emissions [Room H]**	Life Sciences **Healthy Aging and Preventive Medicine [Room B-2]**	Engineering and Innovation **New Engineering Technologies [Room C-2]**	Environment **Utilization of Space and Ocean [Room G]**	Cooperation in S&T **Collaboration among Academia, Industries and Government [Room C-1]**	S&T and Society **Policy Making in Science and Technology based Society [Room K]**	ICT **Cybersecurity [Room B-1]**	Social Infrastructure **Smart and Resilient Cities [Room J]**	Funding Agency Presidents' Meeting [Room E]
	12:30-14:00	Lunch and Networking Time [Sakura]						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 101]
202	14:00-15:10	Plenary Session 202A: **Delivering Healthcare to the World [Room A]**				Plenary Session 202B: **Research and Innovation [Main Hall]**				
	15:10-15:40	Networking Time (Coffee Break)								
203	15:40-17:40	Energy **Future Prospect of Energy Mix (Nuclear, Oil and Gas, etc.) [Room H]**	Life Sciences **Advanced Medicine and Bioengineering [Room B-2]**	Engineering and Innovation **Robotics and Society [Room C-2]**	Environment **Environment and Health [Room G]**	Cooperation in S&T **Science and Technology Diplomacy and International Collaboration [Room C-1]**	S&T and Society **Science and Technology Literacy in Digitalized Society [Room K]**	ICT **Utilization of Big Data [Room B-1]**	Social Infrastructure **Advanced Agriculture and Food Industries [Room J]**	
	17:40-	Move to Tofukuji Temple (shuttle bus provided from ICC Kyoto to site)								
204	18:00-20:00	Special Buffet Dinner at Tofukuji Temple				20:30-22:00	Council Meeting			

October 9, 2018 (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]

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Plenary Sessions

Science and Technology for the Future of Humankind

[Chair]

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

[Speakers]

Abe, Shinzo, Prime Minister, Government of Japan, Japan

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.

Oreshkin, Maxim, Minister, Ministry of Economic Development of the Russian Federation, Russia

McNutt, Marcia, President, National Academy of Sciences, U.S.A.

Nakanishi, Hiroaki, Chairman, Keidanren (Japan Business Federation); Chairman of the Board, Executive Officer, Hitachi, Ltd., 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 15th annual meeting of STS *forum*. Mr. Omi congratulated Prime Minister Abe on his recent election victory and looked forward to his continued support as Honorary Chairman of STS *forum*. He also pointed out that over 1,400 participants were taking part in the meeting this year and thanked them all for their attendance.

Chair: Omi, Koji

Mr. Omi explained that advances in science and technology have brought both benefits and problems to human society. STS *forum* refers to these as the “lights” and “shadows” of science and technology. STS *forum* was launched as a platform to facilitate discussions across government, industry and academia to jointly tackle these issues, looking ahead 500 years in the future.

Abe, Shinzo

However, global conditions have changed in recent years due to the rise in countries’ self-interest. This makes the mission of STS *forum* more vital than ever before. Key issues include balancing energy needs and the environment, as well as economic growth and sustainability. Remarkable advances have been made in ICT, including autonomous vehicles and increased productivity. However, the intellectual property issues and loss of jobs arising as a result of this must be addressed. Other scientific advances and issues must also be looked at from a long-term perspective.

The fundamental aim of STS *forum* is strengthening the lights and controlling the shadows of science and technology. This is more important than ever before. STS *forum* also believes in fostering the next generation. It launched a young leaders’ program four years ago and 150 young leaders are participating this year. STS *forum* also emphasizes the participation of women.

Since the last annual meeting, four workshops have been held around the world. This has helped raise the global profile of STS *forum*. STS *forum* has developed from a meeting to a full-fledged global movement. It is hoped that the discussions among participants at this year’s meeting will contribute to great breakthroughs in science and technology that will pave the way to a brighter future for humankind.

Mr. Shinzo Abe, Prime Minister of Japan, expressed his determination to boost innovation, which is key to a brighter future. In the past, Japan faced a state of despair. However, the Abe administration’s efforts to boost innovation changed this, particularly the acceleration of open innovation platforms under the Impulsing Paradigm Change through Disruptive Technologies (ImPACT) program. This program has broken down silos and achieved

Holliday, Jr., Charles (Chad) O.

unprecedented innovation, such as compact satellites that can be launched on demand and used for disaster response or other purposes.

The ImPACT program uses taxpayers' money and the managers of each of the 16 platforms are held accountable. The managers also engage in friendly competition with each other. The participants in this program will surely form the core of Japan's innovation ecosystem.

Under the policies of the Abe administration, Japanese young people are becoming more active and optimistic for the future. The employment of young people has improved greatly. The administration is also promoting recurrent education. It is hoped that the many people undergoing such education will drive the fourth industrial revolution, which will create new businesses. The Government will support this by filling gaps between institutions and reforming out-of-date regulations.

Through such measures, the Abe administration is determined to create a strong Japan, which will surely benefit the world. Essential to this is enhancing the country's economic growth and innovation will surely play a central role in such efforts.

Mr. Charles O. Holliday, Jr., Chairman, Royal Dutch Shell plc; former Chairman of the Board, Bank of America; former Chairman and Chief Executive Officer, DuPont, spoke about climate change. The Intergovernmental Panel on Climate Change is about to announce a new report. It will surely emphasize that climate change is real and call for accelerated action.

There are three key actions needed by the business community. The first is to share information. Many businesses keep secret information that could broadly benefit society. Shell has shared information about the efforts needed to achieve the target of limiting the temperature rise to less than two degrees Celsius. It will be necessary to achieve net zero emissions by 2070 and drastic change is required to reach this target. For example, by 2050 it must be impossible to buy a car with an internal combustion engine.

Businesses need to work together with governments. It is not enough for businesses to merely operate within their legal limits if that will cause harm to the environment. They must propose policies that really make a difference. Shell recommends setting a carbon price of some kind.
Businesses need to rethink how fast they must scale. The necessary rate of scaling is unprecedented and businesses must accelerate efforts to increase the diffusion of their technologies and the scale of their infrastructure for tackling climate change.

Oreshkin, Maxim

Mr. Maxim Oreshkin, Minister, Ministry of Economic Development of the Russian Federation, began by pointing out the rising instability in the world. Each year, technology is being increasingly used as a weapon. The international community must ensure that technology does not continue to be used as a weapon, but rather as a tool for the shared benefit of the world. The current state of affairs is a threat to sustainable development and efforts must be needed to get science and technology back on the right track.

Russia has set the development of science and technology as a national priority, and is open for cooperation. For Russia, Japan is a key partner. For example, the two countries have worked together to deal with the recovery from the Fukushima nuclear disaster. Russia will do everything it can to ensure that science and technology continues to act as a bridge between the two countries.

Dr. Marcia McNutt, President, National Academy of Sciences, discussed gene editing and AI. It is hoped that progress in gene editing will lead to the elimination of certain genetic diseases and human malformations. However, we must approach such new frontiers cautiously. Today's disability may be tomorrow's advantage. Evolution has shown that it is not the strongest that survive, but the most adaptable, and diversity fuels adaptability.

McNutt, Marcia

As for AI, this technology is infiltrating all areas of human life. Everywhere, AI is operating faster than human brains. However, there are still many areas where the human brain is superior, such as face recognition. The United States has launched the BRAIN Initiative to better understand the wonders of the human brain and use the findings to further develop AI technology.

Mr. Hiroaki Nakanishi, Chairman, Keidanren (Japan Business Federation); Chairman of the Board, Executive Officer, Hitachi, Ltd.; Former member of the Council of Science, Technology and Innovation, presented on opportunities and efforts related to innovation in Japan. Digital technologies have yielded many benefits for society, and it is necessary to accelerate the spread of such benefits. At the same time, such technologies bring downsides that must be minimized. One of the key advantages of digitalization is the visualization of information, which will surely help solve the many problems faced by society.

In Japan's case, these include the rapidly aging society, the declining birthrate, and natural disasters. The Japanese Government set up the target of realizing Society 5.0, a smarter, more information-oriented society that makes great use of digital technologies. Furthermore, it set up the Council on Investments for the Future to gather funding and support for the promotion of technologies that are essential for the future of Japan and the growth of its economy.

Nakanishi, Hiroaki

The realization of Society 5.0 will not be possible without the involvement of the business community and the Japanese Government is working closely together with Keidanren, the Japanese business federation, to that end. The participation of academia is essential as well and collaborative R&D between industries and universities is very valuable.

Sustainable Development

[Chair]

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

[Speakers]

Seko, Hiroshige, Minister, Ministry of Economy, Trade and Industry (METI), Japan

Guo, Ping, Deputy Chairman and Rotating Chairman, Huawei Technologies Co., Ltd., China

Uchiyamada, Takeshi, Chairman of the Board, Toyota Motor Corporation, Japan

Yamanaka, Shinya, Director and Professor, Center for iPS Cell Research and Application, Kyoto University, Japan [Nobel Laureate 2012 (Physiology or Medicine)]

Opening Remarks

Dr. Rush D. Holt, Jr. opened the session by stating that the Sustainable Development Goals (SDGs) are essential for the consideration of the STS *forum*. The SDGs are aimed at ensuring sustainability for all. Science, technology and innovation (STI) are important for implementing and accelerating efforts to achieve the SDGs. Simultaneously, the SDGs are a useful framework for ensuring that STI contributes to global good.

Chair: Holt, Jr., Rush D.

The involvement of national and local governments is important as well. However, local engagement is weak in some countries. There are also many misconceptions among the public and decision-makers. AAAS is working to provide politicians with practical, scientific information that will promote better-informed decisions.

The SDGs are not vague hopes or empty rhetoric. We must work backwards from them to inform our actions today. Japan's efforts to achieve the SDGs are highly commendable. Through the efforts of Japan and others, the power of STI can be fully leveraged for the promotion of the SDGs.

Mr. Hiroshige Seko spoke about achieving a hydrogen-based society. Japan is bullish on hydrogen. It can be a great connector as a highly-portable, highly cost-effective and environmentally-friendly source of power. Hydrogen has so many possible applications. For example, it can be used to power vehicles or manufacture steel.

In Japan, over 270,000 residential fuel cell units have already been installed to power home demand. The country aims to increase the number of units to 5.3 million in 2030. In addition, later this month, Japan will host the Hydrogen Energy Ministerial Meeting, the first meeting of its kind in the world.

Mr. Ping Guo shared his thoughts on sustainable development. There is a saying that 4G changed our lives and 5G will change the world. New technologies and architectures will make networks more flexible and adaptable. They will also enable the application of networks to many different fields. 5G will contribute to the achievement of SDG 17, which is strengthening the means of implementation and revitalizing the global partnership for sustainable development. A good example is the healthcare sector in Japan, where robot nursing and telemedicine is being introduced.

In addition, Huawei is also working with partners in Japan to bring such technologies to other markets, such as China or Europe. The 5G network will bring great benefits. However, the fact that it will connect all people and all things will also raise security concerns. To address this, 5G security will incorporate 4G security with even greater security enhancements. Huawei hopes to bring 5G networks to all households to achieve a smarter and more-connected world. Huawei will continue to work with its partners to unleash the potential of digital technologies, while solving the issues that arise, to achieve a prosperous, sustainable and intelligent world.

Mr. Takeshi Uchiyamada spoke about vehicle electrification. This is essential for reducing carbon emissions. Toyota has a history of actively developing and introducing electrified vehicles to the market, and is continuing to develop such technologies. To accelerate the popularization of electrified vehicles such as the Prius or Mirai, it is necessary that they contribute to resolving social issues. Toyota hopes to have electrified versions of all vehicles by 2020 and to sell 5.5 million units by 2030. Toyota has established a mass production system for the construction of electrified vehicles. Annual production stands at 1.5 million globally. Using its technology and knowhow, Toyota aims to promote the widespread popularization of electrified vehicles.

One potential bottleneck is battery technologies. Toyota recognizes the importance of battery technology and is continuing to make progress in this area. Besides the technologies used in electrified vehicles, social infrastructure, such as hydrogen charging stations, are also needed for the spread of electrified vehicles, and Toyota will work together with the government to promote the development of such infrastructure.

Dr. Shinya Yamanaka began by congratulating Dr. Tasuku Honjo for being awarded the Nobel Prize in Physiology or Medicine. He also pointed out that there is a key difference between Dr. Honjo's work and his own Nobel-Prize-winning research. Dr. Honjo's research relates to a new cancer treatment that is already helping thousands of patients, whereas Dr. Yamanaka's work is in a stem-cell technology that may eventually be used to benefit many patients.

Scientists are steadily creating new medical treatments that bring hope to patients. However, many new treatments are unaffordable except for those who are very wealthy. We need to redefine "success" in the context of medical treatment. Currently, innovation in medical treatments is itself viewed as a success, but true success is to create such new treatments, while also making them affordable for patients.

As an example, Dr. Yamanaka's research center is creating stem cells using cells from donors with specific immune types that will not cause strong rejection reactions when transferred to other individuals. This is much more cost-effective than creating specific stem cells for each individual patient. Three stem-cell lines have already been produced and they alone can cover up to 30% of operations.

Together with academia, the business community should also emphasize the importance of cost-effectiveness. Furthermore, governments and regulators need to find ways to accelerate the approval process without compromising safety. It is hoped that novel medical treatments will be made available to all people in the world.

Discussion

Dr. Holt asked Mr. Seko about the goal of sustainable conditions in the world and the necessary steps today to promote hydrogen technology.

Mr. Seko explained that the barrier to the use of hydrogen technology is the high cost. The challenge is achieving an enabling system. The number of hydrogen production and consumption facilities must be drastically increased. The Japanese Government will mobilize funding to support such efforts. This will make hydrogen technologies more affordable. The Japan has launched a national strategy for the promotion of hydrogen technologies and is committed to implementing it.

Next, Dr. Holt asked Dr. Yamanaka about the costs of medical treatments and if there are any guiding principles for ensuring that such treatments are available to as many people as possible.

Dr. Yamanaka said that it depends on the national insurance systems of each country. In Japan's case, all new medical treatments are covered by the national insurance system, giving all patients access to the treatments, regardless of cost. Until now, this system has worked well, but may not be sustainable in the future with the emergence of new and extremely expensive treatments. Therefore, a shift in mindset is urgently needed.

Dr. Holt then posed questions to Mr. Uchiyamada. What steps should be taken today to achieve a sustainable future? What are the roles of electrified vehicles and hydrogen vehicles?

Mr. Uchiyamada answered that hydrogen energy has huge potential as an energy source for the future. However, there are many challenges for its promotion. One is setting up the necessary infrastructure.

Dr. Holt also asked Mr. Guo about the benefits of 5G and how it can be ensured that the benefits are equally shared by all.

Mr. Guo explained that 5G is a new technology providing more opportunities to connect people to people, people to things, and things to things. This offers many possibilities, such as remotely managing fish farms in a more sustainable manner, or making financial services available to people in remote areas. Of course, collaboration among the various partners is needed to create an environment that enables fair and equal distribution, and access to such technologies.

Mr. Uchiyamada pointed out that industries are entering a new era thanks to the spread of technologies such as big data and AI. Collaboration among industries, particularly among traditional industries and digital industries, will become increasingly important.

Mr. Guo agreed that AI, big data, and cloud technologies will bring different industries closer together.

Dr. Holt suggested that more attention needs to be paid to the sustainability of the SDGs. Furthermore, he highlighted the importance of deciding on actions today by working backwards from the SDGs and of ensuring compatibility among the SDGs.

Mr. Seko presented his vision of a future where hydrogen systems are a social system and where hydrogen cartridges will be widely available to the public. This will make energy available to everyone in the world.

Mr. Guo believed that a better-connected world will be a more sustainable world.

Mr. Uchiyamada thought that setting ambitious shared goals will be important for achieving sustainability. Such goals will help unite the various stakeholders and bring together different technologies for a common good.

Dr. Yamanaka hoped that STS *forum* will be a driving force for overcoming the many obstacles that stand in the way of achieving a sustainable world.

Lights and Shadows of Science and Technology

[Chair]

Yoshikawa, Hiroyuki, Fellow, Japan Science and Technology Agency (JST); President, Japan Science Support Foundation, Japan

[Speakers]

Córdova, France A., Director, National Science Foundation (NSF), U.S.A.

Saito, Ken, Member, House of Representatives, Japan

Moniz, Ernest J., MIT Cecil and Ida Green Professor of Physics and Engineering Systems emeritus; Co-Chairman of the Board of Directors and CEO of the Nuclear Threat Initiative, Massachusetts Institute of Technology (MIT); 13th United States Secretary of Energy, U.S.A.

Lee, Yuan Tseh, President Emeritus, Academia Sinica, Taiwan [Nobel Laureate 1986 (Chemistry)]

Opening Remarks

Dr. Hiroyuki Yoshikawa opened his remarks by emphasizing that the lights and shadows of science and technology are a fundamental focus of STS *forum*. To date, discussions of the lights and shadows at STS *forum* have been limited to specific fields. Now, however, it is necessary to hold more general discussions.

Chair: Yoshikawa, Hiroyuki

Science is an important base of human wisdom and action. The development of science emerged from humans' fights against various threats to their existence, such as predators or natural disasters. New threats have now emerged, in the form of the shadows of science and technology. If new science is introduced too rapidly, it may be difficult to keep up with and mitigate the downsides associated with that science.

It is time to develop a general methodology for preventing the breakout of the shadows of science and technology. Scientists must not only work to create knowledge but also

to promote the use of this knowledge for the good of mankind. Descartes posited three essential rules for understanding something. First, one must decompose something into elements. Then one must try to compose those elements in new assemblies. Finally, one must enumerate all these assemblies. Only then can one truly understand something. The participation of specialists from different disciplines, not only scientists but also experts in ethics and human nature, is necessary for fully understanding the lights and shadows of science. This is a great challenge, but STS *forum* is surely the best platform for taking on this challenge.

Dr. France A. Córdova explained that new technologies offer both opportunities and challenges. For example, communication tools have transformed how we work and how we care for our family members. However, they have also disrupted governments and societies. All fields of science and technology, including space exploration, quantum computing, and AI inherently contain lights and shadows.

For example, we need to have a highly skilled workforce for the future, but how will it be developed? Additionally, while continued progress in AI research has the potential to bring light to schools, workplaces and homes, it also comes with shadows such as issues related to ethics, legality, safety, and standards. Given the many applications of AI, how we tackle such issues could shape the very world we live in.

As demonstrated by the strong partnership between NSF and Japan, if countries, organizations and people work together, evidence-based research can illuminate a path to the future. We need to bring together people across different disciplines to tackle large challenges in science and technology. There should be greater collaboration among government, industry and academia. Scientists should do more to engage the public and decision-makers. The greater participation of women and minorities in STEM fields should be also promoted. All of these should be the common focus of nations around the world.

Mr. Ken Saito spoke about the lights and shadows of science and technology in agriculture. Agriculture is essential for ensuring a sustainable food supply. It is crucial for human life and therefore raises many ethical questions. The population of the world continues to grow. Thanks to innovations in food production, such as disease-resistant plants or self-driving technology, it has been possible to keep this population fed. As such technological progress continues, it is possible that agriculture will reach a new dimension. Advances in AI and in genome editing are particularly promising.

However, due care must be paid to the potential negative aspects, such as the potential impact on biodiversity or water shortages. The public has also exhibited anxiety over new technologies. There is especially deep concern over genetically-modified food. Technological progress occurs very rapidly and new technologies in one field can spread to other fields very quickly, bringing with them also lights and shadows.

There needs to be an appropriate balance between the development and regulation of technologies. Political leaders must take ownership of this. They need to have a correct understanding of new technologies to avoid excessive regulation. They must also be able to communicate accurately and openly with society about these technologies so as to gain public understanding. It is hoped that STS *forum* will continue to engage politicians so as to foster the political leadership needed to maximize the lights and minimize the shadows of science and technology.

Dr. Ernest J. Moniz presented on the three existential threats facing humanity: global warming and climate change, biosecurity and pandemics, and nuclear weapons and the safe expansion of peaceful uses of nuclear energy. Advances in science and technology have transformed societies and the way we live. However, they have also resulted in huge amounts of carbon emissions. Innovations in clean science and technology are essential for reversing this trend. These technologies need to be inexpensive, practical and attractive to both developed and developing countries. Good progress is being made, but it must be further accelerated. All countries need to come together to resolve these technology issues.

At this moment, humankind is not even on a trajectory to achieve the two-degree Celsius target. We must accelerate our efforts and supplement the various clean technologies with large-scale management techniques.

With regard to pandemics, breathtaking advances in the life sciences offer great hope. However, the misuse of such technologies can pose devastating threats to humankind. Such technologies and knowledge must be handled with great responsibility.

As for nuclear technologies, the threat of the use of nuclear weapons is higher today than it was at the time of the Cuban Missile Crisis. There are both security and technology-related factors contributing to this risk. Dialogue, science and technology, and technically-informed officials are key to reducing this risk. Even more than that, verification systems are essential. Regarding nuclear energy, there has never been so much innovation and entrepreneurship in this field, including safer technologies and new funding schemes, which offers reason for optimism.

Dr. Yuan Tseh Lee pointed out that the large questions associated with science and technology are global in scale and cannot be solved by any single country alone. The boundaries between nations are merely lines on a map. STS *forum* has always sought to tackle such global challenges. One such issue is the growth of the human population. Innovation and sustainable development are needed to maintain the necessary living standards for all people in the world, as the global population continues to grow.

International science and technology must be leveraged to tackle these issues and STS *forum* has always endeavored to promote this. An important addition to STS *forum* in recent years has been the Future Leaders' program. This program is aimed at fostering the next generation of leaders who will continue the current work of STS *forum*.

Global warming is another issue that affects the entirety of the world and must be urgently solved. Political leaders have expressed their political will to tackle global warming with the adoption of the Paris Agreement. In 2018, extreme climate events have raised greater awareness of the global warming trend among the public. It is regrettable that more efforts and funds are not being devoted to combat climate change. As fellow citizens of planet Earth, people around the world should stop fighting each other and come together to fight climate change. It is also hoped that developing countries will endeavor to develop sustainably, and not follow the example set by many developed countries of over-development and over-consumption.

There are three key aspects to consider in our mission to stop climate change. Politically, can we unite as a global community? Socially, can we come to a consensus? Scientifically, can we devote the resources necessary to achieve energy breakthroughs? The time to act is now.

Dr. Yoshikawa added some comments before bringing the session to a close. STS *forum* is a unique venue for discussing the lights and shadows of science and technology. All participants, regardless of their area of expertise, have their respective role to play.

Role of Science and Technology Education for Society

[Chair]

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

[Speakers]

Colwell, Rita R., Distinguished University Professor, Center for Bioinformatics and Computational Biology, University of Maryland; Professor, Johns Hopkins Bloomberg School of Public Health, U.S.A.

Abdel Ghaffar, Khaled Atef, Minister, Ministry of Higher Education & Scientific Research, Egypt

Shibayama, Masahiko, Minister, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

Yamagiwa, Juichi, President, Kyoto University; President, Science Council of Japan (SCJ), Japan

Opening Remarks

Dr. Hiroshi Komiyama spoke about the role of universities, students and citizens, including retired seniors, in tackling social issues. He began by explaining how human activity has gradually expanded for most of history and occurred even more rapidly in recent years, especially in the field of knowledge. He elaborated that in the face of today's increasingly complex society, education holds the key to capitalizing on the benefits and mitigating the negative effects of science and technology.

Chair: Komiyama, Hiroshi

Dr. Komiyama then presented two of his experiences characteristic of a new form of education that he would go on to define as "The Borderless College." The first example was of a primary school that, with the helpful participation of university-student tutors, successfully established programming as one of the school's compulsory subjects. The other example was that of collaboration held in Tanegashima between 24 institutions' students and teachers from around the nation who guided local high-school students and residents in proactively planning for the future of their island. Dr. Komiyama proposed this system, "The Borderless College," as a form of education appropriate to today's complex society and distinct in its addressing of social issues by a wide range of people with a university at its core.

Dr. Rita R. Colwell stated that society is becoming increasingly automated, leaving workers with high school educations essentially jobless. For the future, we must train technicians with mathematics and computer expertise at a level that allows them to perform technical jobs.

She also discussed reductions in academic research, which has impacted the benefits of such research for society. A beneficial example of industry-government-academia research was conducted after a gas explosion in the Gulf of Mexico, which yielded many publications, training of numerous people, and information transmission to the public. Finally, Dr. Colwell stressed information provision to the public in a way that is clear and understandable, which requires training scientists in communication. Interdisciplinary cooperation is essential to tackle the social issues of the 21st century.

Dr. Khaled Atef Abdel Ghaffar stated that consideration must be paid to Industry 4.0 and Society 5.0 in looking at the entire process of basic to higher education, as well as STI and the SDGs. More needs to be done for this due to a wide lack of information. In addition, we must consider different cultures when we talk about science, technology, and innovation, as well as the jobs that will vanish in the near future. Otherwise, we will ignore societies with workforces that are not ready to be replaced by AI and robotics, producing detrimental results.

Part of Egypt's reforms include science and technology, including improving the ecosystem for research and innovation and a competitive funding system. This is essential to link the government, academia, and industry. There also needs to be consideration of improving scientific literacy among the public. One aspect is that science and technology can have advantages as well as disadvantages, and it is important that this is understood.

Mr. Masahiko Shibayama stated that Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) is known as the ministry of creating the future. Japan is facing great social changes such as the 100-year life era and declining birthrates, as well as

Society 5.0. The country must now discuss specifically the new age approaching and the measures that can be implemented now. Firstly, MEXT is working on human resource development including discussions with experts and the direction of Society 5.0 measures. It values critical thinking, judgment, and self-expression based on knowledge acquisition and independent willingness for learning. The Ministry has a threefold direction: achieve fair learning, ensure students acquire fundamental academic ability, and transcend the humanities-sciences divide.

Mr. Shibayama then highlighted efforts for university reform. For example, resources need to be diversified to strengthen capacity and enrich management basis. In addition, the quality of research articles should be enhanced through the expansion of human resource mobility and collaborative research across borders. MEXT has encouraged cooperation between public and private universities and with industry. It has also secured young human resources and fostered them. For the 100-year life era, MEXT also promotes recurring education by providing programs based on demands of workers and industries. Education for sustainable development (ESD) must also be emphasized. Through these efforts, MEXT will address a wide range of issues for a society in which no one will be left behind.

Dr. Juichi Yamagiwa stated that national universities are public property, responsible for human resource development as the core of regional development. 75% of graduate students belong to national universities, and these universities carry out advanced science and technology education. Japan is facing a decline in its population which will hit rural areas the hardest, so the country must consider the right ecosystem for its future population size. The Japanese Government has aimed for Society 5.0, the IoT is connecting people and things, and AI and automation are helping overcome societal issues. Through these reforms, it is hoped that a society can be formed with mutual respect and active citizens. An ideal future is being envisioned, and for this, insight from science and technology are indispensable. Our lifestyles are becoming increasingly led by information, and the information industry stimulates our desire to consume.

However, although humans should use information, we also must think about its meaning and substance. We cannot handle the sheer amount of data and we do not know which sources to believe. If individuals become considered part of the data flow, personal independence will vanish. Science and technology could be able to construct individuals and turn our society into one entirely focused on information processing. Before such a reality comes about, we must carefully consider history and our future. In addition, national universities should be reborn for students and the public to connect with education and each other.

Discussion

Dr. Colwell noted that the general theme of all the presentations was that we are undergoing enormous social changes throughout the world. Questions include if universities can change as rapidly as they need to, and who will take the initiative to effect change. Dr. Yamagiwa said that young people tend to seek information on the internet, so there needs to be reform of lectures and a turn toward active learning, fieldwork, and experiments, so students learn from experience as well as information. Dr. Abdel Ghaffar noted that Egypt faces a population increase, in contrast with Japan, with a large young population. He suggested a global symposium covering different cultures and models to create a scenario that fits diverse countries. Mr. Shibayama stated that a declining population necessitates productivity enhancement, so higher education is needed in Japan's local regions. Dr. Komiyama stated that the low birthrate is in fact a net global issue.

Dr. Colwell said that she feels strongly about mathematical education and the need to understand statistics. The way it is taught needs to be enhanced, and mathematics for girls needs to be emphasized. Dr. Yamagiwa asked for ideas to encourage girls to pursue mathematics. Dr. Colwell suggested that encouragement needs to start early. Dr. Komiyama said active learning of mathematics is needed. Mr. Shibayama said that close communication

between teachers and students is essential. Dr. Yamagiwa said that mathematical opportunities for girls should increase from elementary school.

Q&A Session

A participant asked if the Japanese high school exam system is an impediment to improving education. Mr. Shibayama stated that the exam system must be reformed to be based not only on knowledge but also logical thinking and active learning. National curriculum standards are being revised to nurture students.

A second participant stated that scientists need to learn how to communicate in a different way. Dr. Colwell agreed that citizens who pay the taxes to fund research need to understand how that research is meaningful for their lives. Professional communicators can assist with educating scientists. Dr. Abdel Ghaffar said we should have a clear definition for the STI that we can all agree upon and deliver in a message to society.

A third participant put forward that male role models, especially fathers, active in the sciences are important for encouraging mathematics to girls, while female role models are important for encouraging literacy to boys. Dr. Colwell concluded by stating that diverse aspects need to be taken into account for improving education and contributing to society.

Science and Technology in Business and Finance

[Chair]
Liu, Mark, Chairman, Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC), Taiwan

[Speakers]
Endo, Nobuhiro, Chairman of the Board, NEC Corporation, Japan
Hayashi, Nobumitsu, Deputy Governor, Japan Bank for International Cooperation (JBIC), Japan
Lim, Chuan Poh, Chairman, Agency for Science, Technology and Research (A*STAR), Singapore
Rangsiyopash, Roongrote, President and CEO, Siam Cement Public Company Limited (SCC), Thailand
Schick, Hartmut, President and CEO, Daimler Trucks Asia; President and CEO, Mitsubishi Fuso Truck and Bus Corporation, Japan

Opening Remarks

Mr. Mark Liu began by stating that semi-conductor and ICT technology has been one of the key drivers of technological and societal change over the last several decades. These advances which have been guided by continuous increases in computer processing power have given humanity hope for self-driving cars, advanced medicine, and AI amongst other technologies. This device scaling will continue in the mid-term future and provide a platform for further innovation in these areas as well as others. The third and fourth dimensions of semi-conductor architecture will drive this further development and help fuel the insatiable demand of computer technology across multiple industries, as well as enhance quality of life. For there to be continued innovation over the coming decades, additional innovators must be raised, involved, and unleashed, which will lead to the creation of a better society. There are also challenges and hurdles lying ahead which can be combated via the free and full flow of people and ideas.

Chair: Liu, Mark

Therefore, open collaboration is paramount to ensuring we see continued progress in these spaces.

Dr. Nobuhiro Endo began his remarks by making the case that in modern-day society, human activity was the framework for human life. He then emphasized the important role played by businesses and organizations in helping to provide the opportunity to generate activity for humankind. Innovation is often simply defined as a new business model or technology. However, at its core these approaches and solutions should focus on the fundamental needs of humans which are speed and communication. Another important consideration is ethics, and understanding the intersection between these principles and technology and how they should help drive the fundamental requirements of humans and society. This in turn will help drive economic activities. Human society must therefore commit to a scientific approach guided by morals. In conclusion, Dr. Endo noted that Sustainable Development Goals (SDGs) were an important benchmark for all of society, and that placing SDGs at the focus of business, organizations, and governments was becoming increasingly crucial to allow for continued existence of a sustainable world and society.

Mr. Nobumitsu Hayashi explained that, ten years since the financial crisis, there were ongoing challenges around solving global social problems and re-invigorating the world economy. New money is often concentrated in terms of sponsorship or in sectors, such as fintech, AI, or automatic driving. However, risk money or equity investment are important to discover and utilize innovative technologies, while the abundant funds injected by major central banks since the crisis have poured into leveraged loans or real estates. Another important area to focus on is to utilize technologies to preserve and enhance the environment and to develop high-quality infrastructure. In conclusion, Mr. Hayashi noted that since the seeds of another financial crisis were being sown, it was essential for the authorities and the financial community to make best use of knowledge and experiences to build a sustainable world for many generations to come.

Mr. Chuan Poh Lim noted that open innovation was imperative for businesses to remain competitive, but that organizations should also partner with other public and private research performers to ensure their solutions have applicability across a broad range of peoples and problems. An alignment of purpose across multiple parties, industries, and interests could help drive down cost and development time. The key to such collaboration lies between confidence and trust developed through success and failures. Studies have shown that collaborative projects and the opening of the innovation process delivers superior financial

results. The role of government in innovation is to invest in excellent research and research institutions, focus on certain areas and technologies, nurture the next generation of leaders in science and technology, and foster public-private partnerships under an open innovation framework. Public research innovation has grown in Singapore over the last few years, and the government is committed to continuing this trend going forward to maintain Singapore as a global R&D hub. Singapore has become a nexus for international R&D collaboration. Mr. Lim concluded his remarks by stating that a strong research ecosystem was imperative to help companies better serve their markets and the global community.

Mr. Roongrote Rangsiyopash began his remarks by explaining his belief that technology and innovation was a major key pillar of business. Innovation metrics can help drive and plan future company growth, and science and technology capabilities can also be bolstered through working collaboratively with institutions focused on fundamental research and frontier R&D. Another important metric for companies is to measure the amount of high value-added products and services in their offering.

Mr. Rangsiyopash noted that digital and technology disruption was also a challenge, not simply in terms of manufacturing and technologies, but in terms of business models. These challenges can also come from outside traditional industries. This has led to the definition of three key success factors to compete effectively in the future including basing innovation on customer centricity R&D, improving speed in the development of products and services to market timeline by working with outside partners, and working to develop and attract top talent. An Open Innovation strategy that employs digital transformation, builds

a customer-centric culture, adopts a startup approach, changes cultures to be more open to outside ideas, and finds the right mix of talents is essential for larger companies and organizations to stay competitive going forward.

Mr. Hartmut Schick began by stating that scientists and innovators had pushed the bounds of the possible, but that these possibilities also came with a greater responsibility towards humanity at large. We need to understand whom new technologies will benefit and have the appropriate strategies. In the automotive industry, there are three major trends including electric, automotive driving, and connectivity. We must ask ourselves whether there will there be a broader benefit to society in developing these technologies. For example, electric vehicles are an indispensable and necessary technology for sustainable development goals but require new infrastructure and battery technology which will impact society. Similarly, for automotive driving, thorough and robust testing is required as well as the development of a transparent system which clearly outlines the responsibility of the driver, vehicle and software in operating on the road.

Mr. Schick concluded his remarks by stating that as the trends were complex and interlinked, creating a solution for the entire public and not just one customer was essential. It's not just about creating a profitable product but also creating a product that drives sustainable goals.

Q&A Session

There was a question about upcoming technologies which might change both finance and the way of doing business, such as blockchain and cryptocurrencies. It was noted that these technologies could affect the peer to peer relations between customers and companies as well as the financial markets respectively. Mr. Hayashi stated his belief that blockchain was a powerful technology which could bring benefits to the economy but added that a solid regulatory environment and democratic process defining how such technologies could be utilized was a prerequisite.

The final question was regarding when automotive driving would become a ubiquitous technology. In response, Mr. Schick noted that there would be an important transitional phase where both fully automated vehicles and non-automated vehicles would exist in the same environment for several decades before the full transition to an environment where all vehicles were automatically driven.

Society Changed by ICT

[Chair]
Kitano, Hiroaki, President & CEO, Sony Computer Science Laboratories, Inc., Japan
[Speakers]
Sakuyama, Masaki, Chairman, Mitsubishi Electric Corporation, Japan
Copan, Walter G., Director, National Institute of Standards and Technology (NIST), U.S.A.
Veloso, Manuela, Head, Artificial Intelligence Research, J.P. Morgan, U.S.A.
Huber, Bernd, President, Ludwig-Maximilians-Universität (LMU) München, Germany
May, Gary S., Chancellor, University of California, Davis, U.S.A.

Opening Remarks

Dr. Hiroaki Kitano opened the session and spoke about how AI and ICT are changing society. The revolution led by AI and ICT will transform the Internet of Things (IoT) into the Internet of Abilities (IoA), where knowledge and abilities will be commoditized. High-level intelligence and abilities will be accessible on the spot. This will in turn transform industries and governments. To utilize these new capabilities, industries and governments will need to be AI-ready. The provision of access to AI, robotics, and knowledge to people who would otherwise be marginalized or disadvantaged should promote diversity and social inclusion.


Chair: Kitano, Hiroaki

Mr. Masaki Sakuyama presented his vision of a society that leverages IoT, AI, big data and ICT, as well as Japan's concept of Society 5.0. Remarkable advances in ICT have transformed our lives and can lead to the creation of an ultra-smart society. Japan has defined Society 5.0 as a human-centric society. The public and private sectors are working together to realize Society 5.0. These efforts will create new value for society, reduce disparities in society, and help realize the Sustainable Development Goals (SDGs).

Mitsubishi Electric is also doing its part to realize Society 5.0. 15 years ago, Mitsubishi

Electric launched the e-F@ctory, an integrated automation system for factories. In 2010, it established the e-F@ctory Alliance, a third party referencing program for automation solutions that connects manufacturing businesses around the world. Mitsubishi Electric is also part of the Edgecross Consortium, which is aimed at fostering an open software platform for edge computing capabilities. The company is also providing core technologies for autonomous driving: high-precision positioning and high-precision 3D-mapping. In addition, Mitsubishi Electric is advancing AI technologies that will make deep learning and data analysis easier. The company is committed to realizing Society 5.0 as a means to fulfil the SDGs.

Dr. Walter G. Copan stated that humankind is living in exciting times. Advances in science and technology offer much hope for society. However, it is critical that we take the right steps to ensure that we continue to advance science and technology for the good of society, while mitigating the negative aspects arising from such advances. ICT has transformed our world and the way we lead our lives. We need to create an ecosystem that promotes further innovation in ICT, while addressing concerns such as privacy and cybersecurity. This requires a balance between policy and technology measures.

NIST works to develop guidelines and frameworks that provide value for society, without providing additional regulation that hinders progress and convenience. One-third of the organizations in Japan, as well as other organizations around the world, have adopted NIST's Cybersecurity Framework. NIST is now developing a new privacy framework that is risk-oriented and outcomes-based. AI is having a dramatic effect on our lives and NIST is working to create tools and standards that foster trust around AI and open up its so-called "black box."

The next revolution will occur in quantum science, driven by new measurement technologies at the quantum level. This revolution will yet again transform our lives and provide us with access to even more powerful technologies.

Dr. Manuela Veloso discussed advances in AI technologies. The science of AI has really emerged recently. It integrates information, enables the processing and understanding of data, and selects actions to create the ultimate artificial assistance. In the past, AI research was slowed by a lack of data and the need for knowledge engineering. However, since the mid-2000s, society has created huge volumes of data about almost anything, thanks to advances in ICT, and this has helped to propel AI research.

Currently, AI research is aimed at combining numerical data with a wide range of other types of data such as images, text, or listening. This is very complex. Progress can still be made in many new areas of AI research. Humankind is still one leap away from a true AI revolution. AI is also a science so the AI revolution will not happen overnight. It will be a progressive and incremental change in our lives.

Unlike past technologies, AI is accessible to all. AI may lead to job disruption and give rise to other fears. However, it is also helping to resolve this job disruption, for example by enabling more personalized job training. AI has also helped promote novel collaborations between academia and industry.

Dr. Bernd Huber spoke about the relationship between universities and AI. This is mainly characterized by two factors. Universities act as drivers of the digital revolution, by advancing key technologies like quantum science. At the same time, universities are affected by the digital revolution at all levels and must adapt to it. For example, AI will transform the job market, which in turn changes educational needs.

Universities shape the digital revolution through research and teaching, while also making sure to adapt to the challenges of the digital revolution. Adapting to new developments can be difficult for universities, but the opportunities are well worth it.

Dr. Gary S. May discussed some of the social issues arising from advances in ICT. ICT has enjoy exponential growth in recent years thanks to boundless ingenuity. However, the advances in ICT also raise a number of social concerns. For example, the massive volume of knowledge available has made it difficult to intelligently interact with the knowledge available to us. It is also difficult to determine what information is reliable or not. There has been a spread of misinformation as well. Furthermore, the conflict between speed and accuracy keeps accelerating. In addition, social media has enabled people to select information that only reinforces their own existing beliefs.

Educators are uniquely equipped to empower young people and society at large with the necessary critical thinking to navigate this new landscape, such as discernment, inquiry and information synthesis. There has also been an emergence of movements that encourage teachers to promote the information and media literacy of their students.

Discussion

Dr. Kitano asked what measures can be taken by universities to adapt to the changing ICT environment.

Dr. Huber answered that one of the major requirements for universities in this new age is to ensure that students acquire the necessary ICT competencies to be best equipped for the job market.

Dr. Veloso added that Carnegie Mellon has started the first-ever bachelor's degree in AI.

Dr. Copan commented that a critical element is managing the pipeline of talent coming into the AI field.

Dr. May pointed out that as knowledge becomes more ubiquitous, the role of educators will change from providing information to teaching students how to navigate this information.

Dr. Kitano asked Mr. Sakuyama for the perspective of industry.

Mr. Sakuyama explained that AI and ICT are tools for social good and Mitsubishi Electric is concentrating on the application of these tools to solve social issues.

Dr. Kitano then asked the panelists about how AI can be used more effectively and areas where collaboration is greatly needed.

Dr. Copan cited the importance of having a set of tools for enabling the effective management of privacy issues. Creating an environment of trust is also essential.

Dr. Veloso pointed out that, as AI-human interaction increases, there is a need to examine AI algorithms more closely and understand them more deeply. It is absolutely necessary to challenge AI systems to make them more transparent and to provide feedback that the systems will incorporate. These considerations are at the core of JP Morgan's AI research.

Dr. May felt that more collaboration is needed between computer scientists or engineers and social scientists, such as ethicists or economists.

Q&A Session

A member of the audience asked if there will be more or less disparity and fractionalization in society as people are able to access ever larger amounts of information.

Dr. May pointed out that it could be argued that this access is leveling society. At the same time, there is the economic reality that not everyone has tools to access this information. It has also created bubbles of people who only interact with other people who think the same way.

Dr. Copan believed that democratization of information access has provided great value to society but acknowledged that there are still many parts of the world that lack access.

Closing Remarks

Mr. Sakuyama reiterated Mitsubishi Electric's aim to leverage ICT to create greater value for society.

Dr. Copan said that ICT has brought about economic transformation and greater connectivity. It has sparked revolutions in many fields such as medicine, material science and space communication. Society must make the most of these advantages while managing the risks.

Dr. Veloso believed that this is a moment of great change and also great challenges. These challenges need to be addressed at the educational level. Interdisciplinary dialogue and collaboration will also be important.

Dr. Huber highlighted the importance of universities engaging the public and providing a forum for members of the public to engage with and learn about these new technologies, including the benefits and risks associated with them.

Dr. May believed that academics and technologists need to make greater efforts to educate the general public and collaborate with people in other disciplines.

Dr. Kitano stressed that the benefits of AI should be made available to all. He also believed that AI research should continue to be advanced. AI will also change education and educational needs, and universities must adapt to this. Finally, international collaboration will help promote AI research while also mitigating the downsides.

Delivering Healthcare to the World

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

[Speakers]
Caforio, Giovanni, Chairman & CEO, Bristol-Myers Squibb, U.S.A.
Hamburg, Margaret A., Foreign Secretary, National Academy of Medicine; President, The American Association for the Advancement of Science (AAAS), U.S.A.
Ottersen, Ole Petter, President, Karolinska Institutet, Sweden
Utsunomiya, Osamu, Director-General, Health Service Bureau, Ministry of Health, Labour and Welfare, Japan

Opening Remarks

Dr. Henry A. McKinnell opened the session by bringing up concerns that current healthcare systems are not sustainable and the need for the right leadership to effect change. He then gave an example of fire departments and police departments that provide advice on fire and crime prevention, but noted that there is not the same sort of approach with hospitals.


Chair: McKinnell, Henry A.

We are entering an age of innovative new healthcare, but we still face diverse issues. For example, drugs take too long to be developed and are often far too expensive. While we celebrate new advances, we also have to take a step back and make sure that our system is sustainable.

Dr. Giovanni Caforio discussed the current status of innovation. We have made excellent progress during the last 100 years, but we are on the cusp of even more extraordinary progress, including breakthroughs on cancer and AIDS. For example, Bristol-Myers Squibb's work on Immuno-Oncology shows the critical role that partnerships can play, especially between academia and industry, that accelerate the delivery of new treatment to patients.

A global collaborative research ecosystem has also been created for the fight against AIDS, and we now have a model that can be deployed and improved to fight other diseases. For this, we must be dedicated to innovation, partnerships, and compassion. For innovation, we need government support and support for innovators. For partnerships, ambitious shared goals, engaging respective competencies, and overcoming stereotypes are essential. For compassion, we must make it our goal for all patients to have equal access to new medicine.

Dr. Margaret A. Hamburg stated that although gains have been made in healthcare around the world, issues still remain that require a comprehensive vision that must be acted upon. She highlighted public health, healthcare coverage, healthcare quality, and using science to drive solutions. Universal coverage is being pursued around the world, but around half the global population still lacks access to even basic healthcare. In addition to actually delivering care, quality of care is also an important aspect. Millions of deaths per year occur because of poor care. In our pursuit of universal coverage, we must remember that simply providing low quality care could actually be detrimental.

We also must find better ways to translate technology into products while maintaining oversight and regulation to ensure the benefits outweigh the risks. Focus is also needed on public health measures, improving social factors such as education, housing, and transportation, and the recognition that healthcare is intricately connected with economic growth and national security.

Dr. Ole Petter Ottersen focused on what medical universities can do for healthcare, focusing on the Three Cs: cross-sectoral thinking and action, capacity building, and cost efficiency. Delivering healthcare to the world in an equitable manner is a formidable task that requires cooperation across disciplines and political sectors. Health is very much determined by decisions made in arenas outside of the healthcare system. For example, trade agreements significantly impact health, and universities are in a good position to analyze those impacts. Dr. Ottersen emphasized that the SDGs are beneficial for thinking across different arenas.

For capacity building, Dr. Ottersen noted that two-thirds of the world's population has no access to safe and affordable surgical and anesthesia care when needed. This shows the urgent demand for improving capacity. Universities should encourage internationalization and foster collaborative links to recognize capacity building as one of the most important tasks. For cost efficiency, universities should use their innovative power not only to develop new approaches to diagnosis and therapy, but also to come up with solutions that are

affordable and can be sustainably introduced in resource-poor settings. An innovative coupling of medicine to novel technologies and artificial intelligence can help secure equitable healthcare and accelerate capacity building.

Finally, an increased emphasis on prevention is required to shoulder the increasing burden of non-communicable diseases and to minimize the risk of future pandemics. Initiatives like the Coalition for Epidemic Preparedness Innovations (CEPI) are important since they are set to speed up the development of vaccines regardless of commercial potential.

Dr. Osamu Utsunomiya spoke about Japan's countermeasures against infectious diseases. Japan's accomplishments include the recent conferment of the Nobel Prize to Dr. Satoshi Omura for his work with microorganisms, Japan's international cooperation against parasitic diseases, and the Hashimoto Initiative.

Japan has especially made strides with tuberculosis, once the leading cause of death in the country, and now gives extensive support for international cooperation such as through the Japan International Cooperation Agency (JICA). Based on this experience, the Japanese Government has led a declaration of increased funding at the recent High-Level Meeting on the Fight Against Tuberculosis of the United Nations. Japan also works against pandemic influenza, including Shionogi & Co.'s development of the influenza drug Xofluza. The Japanese Government will continue to develop capacity and technology through cooperation with pharmaceutical companies.

Discussion

Dr. McKinnell noted that the Abe administration has been instrumental in addressing Japan's previously slow approval of new drugs. He then brought up concerns about high costs of new drugs, pointing out the reasons behind cost structures. Cost effectiveness needs to be pursued to achieve sustainability, such as recognition that an expensive drug might prevent even more expensive health issues in the future.

Dr. Caforio stated that the cost of medicines has remained a relatively constant percentage of the total cost of healthcare in most countries. Surprisingly, it is lower in the United States, but only because the overall cost of healthcare is so high. The pharmaceutical industry takes the affordability issue very seriously and hopes for cooperation to improve it, including more incentives to innovators and tier pricing.

Dr. Hamburg said that we need an overall picture of how all the components align in the healthcare issue and to look for ways that the components are not working well together. She also underscored that advancing science can help bring down costs, including by creating much more targeted therapies. She also stressed partnerships, noting that when the FDA got involved in the development process, years could be taken off because the reviewers could provide advice on strategies.

Dr. Ottersen noted that the cost issue has two sides to consider: both developing drugs and prevention. The only way to have a sustainable healthcare system in the future is to place an emphasis on prevention, especially precision prevention and not just precision medicine and treatment. Dr. Utsunomiya said that Japan needs to become better at translational research. Japan has tackled delayed drug approval by creating the SAKIGAKE Designation for an accelerated approval system for promising future drugs and a conditional early approval system.

Dr. McKinnell noted that it has been argued that technology is part of the problem. Dr. Caforio stated that we need models in which innovators are rewarded for the value they create, not just the cost per unit. A reimbursement model is being explored in which payment is only given if the patient receives a benefit from the drug. Dr. Hamburg brought up the backlash against the hepatitis C drug because of the cost despite its benefits. She also noted that we need to make sure that existing drugs are affordable, given that effective medicines are already available yet not reaching the people who need them.

Q&A Session

A participant asked about the role of screening and new technologies in healthcare cost containment. Dr. Hamburg said that screening is very important but is still an undeveloped area of medical care that needs more investment and the application of new science and technology. Dr. Ottersen stated that there is great potential for combining screening with new technologies, such as using AI and digital tools.

Dr. McKinnell pointed out that corporations and governments should recognize the importance of screening to control costs, but noted that challenges include false positives that have led some to recommend not screening for certain issues, as well as the fact that people do not always act on screening results. Thus, increased investment is needed in behavioral science. Dr. Hamburg agreed that behavioral science is important, stressing that education about positive health habits needs to start from an early age. Dr. Caforio said that patients need to be empowered to be at the center of managing and making decisions on their own health. Dr. Ottersen pointed out that healthcare is political, such as trade restrictions that prevent some countries from having certain labels on foods.

Another participant stated that the issue is not just drug prices, but also intertwined with demography and other aspects. A third participant stated that there needs to be better education for the general public about the process of developing new drugs. He also asked about patients being charged the same amount for a drug whether they derived a benefit or not. Dr. Caforio highlighted that some governments are working on payment for value delivered, which he supports.

As part of the concluding comments, Dr. Utsunomiya said that cost effectiveness is important for healthcare systems. Dr. Ottersen stated that drug development is of course important, but we also need a clear focus on how to build comprehensive healthcare systems in those countries that do not have them. Dr. Hamburg emphasized that without health, there is no hope, and we must consider it for all policies as it is intertwined with all other aspects of our lives. Dr. Caforio stressed that STS *forum*, which brings together diverse stakeholders from all over the world, is extremely important for addressing healthcare systems.

Research and Innovation

[Chair]
Wiestler, Otmar D., President, Helmholtz Association of German Research Centres, Germany
[Speakers]
Al-Salem, Nabeel H., Chief Advisor Partnerships, Research, Development and Innovation, Qatar Foundation, Qatar
Kato, Isao, Managing Executive Officer, Nuclear Power Division, Tohoku Electric Power Co., Inc., Japan
Muromachi, Masashi, Executive Adviser, Toshiba Corporation, Japan
Rosenbaum, Thomas F., President, California Institute of Technology (CALTECH), U.S.A.

Opening Remarks

Dr. Otmar D. Wiestler began by stating that all nations were facing major issues related to the Sustainable Development Goals, and that to cope with these challenges, a variety of approaches would need to be taken in different nations by different organizations, in a wide-ranging number of fields. Economic success builds on the brains and hard work of people, particularly in countries that lack natural resources such as Germany. University and academic research centers, as well as industrial organizations, contribute to this strategy. Long term institutional funding is essential to ensuring that proper resources are allocated towards a systematic approach of tackling complex major challenges facing society, science, and the economy. The focus of the Helmholtz association in Germany includes energy, climate, biomedical research, air and space, transportation, the structure of matter, and the development of future and key technologies with a focus on information technologies. Breakthroughs in fundamental research in this setting are essential drivers for innovation. Forums such as STS are important as they create spaces for researchers, scientists, and representatives from industry to come together and share ideas. In conclusion, Dr. Wiestler noted that strategic partnerships with industry and creating startup ecosystems are among the strategies in which Germany could explore future innovation potential.

Chair: Wiestler, Otmar D.

Dr. Nabeel H. Al-Salem stated that one of the key approaches to achieve prosperity for nations was the sustainability of their economy, and human and social development. Qatar is a small country in terms of size and population, but rich in energy resources. One of the visions of Qatar is to diversify the economy through community development and the promotion of education. A nationwide culture of research and innovation ecosystem fostering is essential for Qatar and similarly sized countries. Research funding agencies in Qatar work collaboratively with other institutions both locally and globally to help promote human capital and infrastructure for research. These strategic partnerships can help develop key talent and lead to further innovation and commercialization of high-tech products and market ready technologies. Another relevant approach is to capitalize on existing capabilities through a focused agenda on several challenges such as cyber, water, and energy security, and integrated healthcare. Qatar has seen success in such an approach with increases in publication output, numbers of researchers, and collaborative research projects, which demonstrates the efficacy of such a strategy. Dr. Al-Salem concluded his remarks by stating that increasing capacity and capabilities would help Qatar become a contributing partner globally in the areas of full security, urbanization, intelligent transportation, renewable energy, and environmental sustainability.

Mr. Isao Kato began his presentation by making the point that the Onagawa Nuclear Power Station was closer to the epicenter of the 2011 Tohoku earthquake and tsunami than Fukushima Daiichi Nuclear Power Plant but did not suffer any major structural damage and did achieve safe cold shutdown. Innovative design must consider past failures and successes. For example, Onagawa Nuclear Power Station was built with a higher ground level than Fukushima, which was one of the major reasons why the power plant was unaffected by the tsunami. This decision was based on old historical records as well as an ultra-safe approach taken by engineers during design and construction of the plant in the 1970s. The point is that major industrial facilities and nuclear power plants can be designed “safe” as intended, but we must be humble and recognize the limitations of our own knowledge and analysis in doing so. Mr. Kato concluded his remarks by stating his belief that old wisdom could have great significance for future innovation, with Onagawa Nuclear Power Station being the proof.

Mr. Masashi Muromachi began by explaining that the Society 5.0 strategy in Japan sets out to create a flexible, self-sustaining society that aims for an optimal societal and economic strategy. We need to make extensive use of AI as a part of this strategy. Two case studies exemplify this essential need. First is the existence of state-of-the-art factories with A.I. technology by global standards. In 1984, Toshiba invented the nonvolatile NAND flash memory. Yokkaichi Operations, Toshiba's main NAND flash memory factory, acquired a vast amount of data, some 2 billion data points from over 5,000 items of equipment used in memory manufacturing every day. In these factories, A.I. technology allows the pinpointing of issues and for systems to make prompt changes when defects occur. This shortens the time required for estimating the cause of such failures to 1/3. This A.I. technology is the basis of speech recognition for car navigation systems, and Toshiba has an 80% market share in Japan. A.I. technology for integrating and analyzing large amounts of data from sensors is the basis of the efficient running of various systems in such factories. The second case study involves power demand forecasting systems. The addition and proliferation of solar power and other renewable energy adds uncertainty to the forecast, which is traditionally based on weather and other information. However, advanced forecasting systems are being developed which are making it possible to more effectively run power plants as well as result in better cost savings. Recent advances in A.I. allow us to further extract valuable data and utilize this capability elsewhere.

Dr. Thomas F. Rosenbaum began by noting that he would focus his comments on the relationship between basic and applied science. The boundaries between basic research and technological applications are becoming increasingly fluid and porous. Mastering fundamental science is essential for realizing the full promise which technology has to offer. Real-world examples include prosthetic limbs, which require understanding the structure of the brain, or creating more efficient ways to mix chemicals to create new enzymes, which require harnessing the ideas of evolution to modify proteins. This approach has implications for universities, industry, and society. For example, rather than train students for a specific job, we must teach students to use quantitative skills to frame solutions and to ask the next set of illuminating questions. In terms of next steps forward, we need a broader and more cohesive university-industrial-entrepreneurial ecosystem and to make a better case to the public of the meaning and purpose of higher education.

Discussion

Dr. Wiestler asked how we can nurture the next generation of scientists.

Dr. Al-Salem said that devoting special attention towards human capacity for innovation was important. He highlighted the Qatar National Research Fund, which aims to bring together local research communities and international organizations and provide funding for both parties as one such example.

Dr. Wiestler asked what kind of A.I. including human talents were required to implement the Society 5.0 Strategy.

Mr. Muromachi answered that talented human resources were required, but that they were facing difficulties to hire bright new talent. He added that globalizing engineering resources within Japan was one of the strategies required to address these shortcomings.

Dr. Wiestler then asked about entrepreneurship promotion at Caltech.

Dr. Rosenbaum stated that the institution actively promoted entrepreneurship, adding his observation that there was a generational change with many young researchers wanting to change society.

Dr. Wiestler asked about the ongoing discussion in Japan regarding future utilization of power plants.

Dr. Kato explained that most nuclear power plant reactors were still non-operational in Japan, and that due to a lack of natural resources in the country, nuclear energy was a necessity to help provide power to support society.

Next, Dr. Wiestler asked about lessons learned in terms of successful public/private partnerships.

Dr. Al-Salem stated his belief that there were numerous benefits from bringing national and international, as well as public and private institutions together. He added that tackling all problems was not the right approach, but rather that a few priorities and goals should be identified.

Dr. Rosenbaum noted that robotics and medical technology were some of the areas where public-private partnerships had shown results in the past. However, he warned that such partnerships could be difficult, and that there were complications around how problems were defined and the possible mismatch of timescales amongst other challenges.

Q&A Session

There was a question about fundamental and basic research associated with data science and its influence on models and mechanisms. Dr. Wiestler answered that more learnings and validations of potential hypothesis were still required. Dr. Rosenbaum agreed, adding that for the next several decades, there were possibilities for basic science to be enriched by machine learning, but not replaced.

Development and Sustainability for the Future of Humankind

[Chair]

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

[Speakers]

Alberts, Bruce M., Chancellor's Leadership Chair in Biochemistry and Biophysics for Science and Education, University of California, San Francisco (UCSF); former President, National Academy of Sciences, U.S.A.

Durongkaveroj, Pichet, Minister, Ministry of Digital Economy and Society; Thailand

Matsuo, Seiichi, President, Nagoya University, Japan

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)]

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

Opening Remarks

Chair: Hunt, Tim

Dr. Tim Hunt began by discussing a 1945 essay by George Orwell — "What is Science?" — noting that it reminded him that, despite huge advances in science and technology, human affairs largely remain the same. The essay highlights the importance of science education and "the implanting of a rational, skeptical and experimental habit of mind." In history, society has swung between not valuing science at all to valuing science above all else. Science, though valuable, is only one important point of view. The humanities should not be forgotten. In addition, scientific education should not only involve the rote learning of facts. Rather it should teach people to think clearly and imaginatively for themselves.

Alberts, Bruce M.

Finally, Dr. Hunt shared a quote from Confucius about wisdom. The man who learns but does not think is lost. The man who thinks but does not learn remains puzzled. Wisdom is saying that you know something when you do in fact know it, and admitting that you do not know something when you do not.

Dr. Bruce Alberts presented on ways to improve the education system. In a world dominated by social media spewing out fake facts, and where the public is often unable to distinguish between truth and falsehood, we need to change the nature of education. Rote memorization of facts is not the right approach. It is critical that education instead focus on engaging students in using critical thinking to make decisions based on evidence, at all levels from age 5 through college. This can be taught even at the youngest levels and simply requires the appropriate educational environment. Better testing methods are also needed.

Furthermore, new tools are needed for spreading good methods for science education. These tools must be actually implementable by teachers. It is no use developing highly advanced curricula that teachers are not equipped to use.

In addition, it is necessary to create a science of education and continuously improve education through research. STS *forum* could be a very useful platform for promoting better education and sharing best practices for education.

Dr. Pichet Durongkaveroj spoke about the impact of the digital revolution. The advent of the internet generated great excitement in Thailand. However, it brought with it concerns such as privacy or security. Since then, even more wondrous progress has been made in ICT, bringing many benefits to our lives. At the same time, these advances have produced new challenges as well, such as cyber threats and misinformation.

As these technologies continue to advance, they may bring connectivity, convenience and efficiency to many societies. At the same time, many nations will be less or least-technologically developed. Who is to say which side is happier or better off? It is important to strike the right balance. There will surely continue to be many downsides that we must deal with as well, such as cybersecurity or online fraud. Solving these problems may not be easy, but we must start examining them and preparing ourselves now.

Thailand has some lessons it can share with the rest of the world. First, public-private partnerships are important. For example, Thailand has created city development companies that develop local provinces with the support of local and national governments. Thailand also recognizes that it cannot continue to be a net importer and net consumer. Thailand is also pursuing digital governance, which will revolutionize its bureaucracy. Lastly, human resources development for the digital world is important as well.

Dr. Seiichi Matsuo spoke about global issues and the approaches that are required to solve them. The establishment of STS *forum* was aimed at utilizing science and technology to solve the issues facing mankind, including poverty and disparity, conflicts, abnormal weather and disasters, energy and food problems, and political instability. We live in the age of the digital revolution. The world is changing at an unprecedented scale and

Durongkaveroj, Pichet

Matsuo, Seiichi

Yonath, Ada E.

speed. Cooperation and co-creation among different fields will be essential for solving the problems that the world faces. Similarly, innovation cannot be created without transnational cooperation and co-creation.

The SDGs represent shared goals for the international community for solving the major global issues that we face. Universities have their own role to play as well. They must promote cutting-edge research and foster the leaders of the future. STS *forum* is a valuable venue for discussing how science and technology can contribute to the sustainability of mankind, while recognizing both the lights and shadows of science and technology.

Dr. Ada E. Yonath discussed antibiotics. The discovery of antibiotics transformed people's lives and greatly increased human life expectancy. At the same time, longer lives also increased the incidence of other diseases such as cancer or Alzheimer's, which are more prevalent among the elderly. Another issue is that the use or perhaps overuse of antibiotics has resulted in the spread of strains of bacteria that are resistant to antibiotics.

Despite this, pharma companies are doing little to develop new and better antibiotics in response. New funding schemes emerged to fund the relevant research, and promising results have emerged, but still pharma companies have been hesitant to participate in developing new antibiotics based on this research. They must be convinced.

Mr. Koji Omi expressed his deep appreciation to the participants for their attendance at the 15th annual meeting. He then described some of the major outcomes of the discussions at the meeting. Climate change mitigation is essential for a sustainable future. New energy solutions can help manage energy supply and demand more sufficiently. Nuclear energy as a low carbon energy source should remain an important source of energy, under the conditions of safety, security and non-proliferation.

In life sciences, advances in gene therapy and pre-emptive medicine are promising. Gene technologies can also help solve food crises if applied to plants and livestock.

ICT innovation is welcome, but effective measures must be taken to ensure security, privacy and job creation.

Governments must encourage businesses to reduce pollution and energy depletion. They must also develop sustainable socioeconomic systems. More open frameworks of exchange are needed as well.

Omi, Koji

Nurturing the future generation is vital and that is why STS launched the Future Leaders program. This year, 150 Future Leaders took part in the annual meeting. The participation of women is also essential. STS *forum* has grown from a mere conference to a global movement, and will continue to work to strengthen the lights and control the shadows of science and technology.

Concurrent Sessions

Key Messages from Concurrent Sessions

[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]

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

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

Chubays, Anatoly B., Chairman and Chief Executive Officer, RUSNANO Management Company LLC, Russia

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

Candel, Sébastien, President, French Academy of Sciences, France

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

Kotani, Motoko, Executive Director, RIKEN, Japan

Onishi, Takashi, President, Toyohashi University of Technology, Japan

[Future Leaders]

Nkansah, Marian Asantewah, Senior Lecturer, Department of Chemistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Grånäs, Oscar, Researcher, Physics and Astronomy, Uppsala University, Sweden

Chair: Gruss, Peter

Opening Remarks

Dr. Peter Gruss opened the session by congratulating STS *forum* on the holding of a very thought-provoking and fruitful 15th anniversary event. STS *forum* is designed to look closely at science and technology and their impact on society. There are many major societal questions that need to be answered such as whether or not we can halt climate change, how the next industrial revolution will change society, whether or not robots will lead to job loss, whether or not we can maintain privacy in the age of big data, and whether or not we can sustain our life on planet Earth. These questions were addressed in the concurrent sessions.

Goldstein, William H.

STS *forum* brings together people from government, industry, and academia to discuss real-world problems and the solutions science and technology can provide. These discussions must occur at a global level. The participation of the future leaders in these discussions is also very welcome. Now more than ever, it is essential to consider the lights and shadows of new science and technology. Government-industry-academia collaboration has been and will continue to be essential. The efforts undertaken by developing countries are also highly commendable.

Overall, good progress is being made. Research and development are making important advances. Nonetheless, countries need to strengthen publicly-funded research, which has the potential to produce the breakthroughs for tackling the issues faced by society. One of the hardest challenges ahead will be achieving a united approach for solving these issues, such as the provision of sustainable energy.

Dr. William H. Goldstein summarized the discussions from the concurrent sessions on energy. Energy creates and increases wealth and wellbeing. However, its shadows include climate change, risks of nuclear proliferation and the perpetuation of inequity. In terms of policy, setting goals for energy mix and planning for energy grids are largely national endeavors, but regional coordination would be useful. For developing nations, “leap-frogging” from fossil fuel-based energy sources to renewables would be an effective means of reducing CO_2 emissions, but can only be achieved through international sharing of technology and investment. Energy is undergoing a transformation. Renewables are becoming less expensive and competitive relative to fossil fuels, even without subsidies. Nonetheless, fossil fuels are here for the long-term due to existing infrastructure and its use as a feed stock. That said, there are many opportunities for reducing the carbon emissions of fossil fuels.

Collins, Mary

There has been a real flowering of technology in the past ten years, which offers hope. However, the future is uncertain. Most innovation that can be foreseen is incremental, but more disruptive innovations are needed to tackle the problems we face. At the same time, in many areas, we are on the cusp of making significant breakthroughs. Continued investment and support is needed. Life-cycle analysis and a systems approach are also required. Additionally, it is necessary to integrate advances from a broad range of technologies, such as AI or digital manufacturing. Overall, there was broad agreement among the participants in the energy sessions on how supply and demand will evolve, the need for continued innovation, the importance of sophisticated analysis of life-cycle costs, the need to engage policymakers, the necessity of greater efficiency on the demand side, and the need to look at technological solutions from a wide range of fields.

Dr. Mary Collins presented the key messages from the life sciences track. There have been remarkable advances in life sciences. Gene editing allows us to rewrite the book of life. However, the delivery systems for gene editing are still relatively inefficient so it can only be applied to a small numbers of cells. There is some frustration among scientists that the European Court of Justice ruled that gene-edited organisms should be treated as genetically modified organisms. That said, it was recognized that better communication about such technologies is needed. Sophisticated PR techniques are needed to correctly convey the cost-benefit ratio to the public, which is becoming increasingly skeptical of science. There is a need for some kind of international standard or framework, and also an appropriate model to price advanced medical solutions.

The second session dealt with healthy aging. It was noted that Japan is at the forefront of dealing with problems associated with the aging of society. The session also discussed the emergence of new regenerative therapies. New diagnostic techniques are also emerging. However, such technological advances will not solve all the health-related problems that we face. Our goal should be personal satisfaction, not perfect health. To that end, physicians need to be part of a multidisciplinary care that moves from hospitals to communities. Lifestyle and diet are key components of healthy aging as well.

Chubays, Anatoly B.

In the third session, on advanced medicine and bioengineering, it was noted that new technologies have been developed for detecting microbes in hospitals and labs. Systems medical science is another important field and it was noted that research and clinical data should be better linked. Value-based healthcare was also discussed. In addition, the participants spoke about the role that governments can play in incentivizing, regulating and making available new medical technologies.

Dr. Anatoly B. Chubays spoke about the messages from the engineering and innovation concurrent sessions. Businesses must aim to realize a new industrial paradigm: a zero-impact industry. New technologies brought about by engineering and innovation are essential for achieving this.

However, there are three challenges that stand in the way. These are measuring progress towards achieving a zero-impact industry, the social impact of technological advances such as the effects on the labor market, and new moral boundaries and ethics.

Dr. Adel El Sayed Tawfik El-Beltagy reported the outcomes of the discussions on the environment. There is a lack of capacity that is delaying responses to global environmental issues, at a time when speed is of the essence. Local communities in particular lack the necessary capacity. Platforms and partnerships involving a wide range of stakeholders are needed to build this capacity.

El-Beltagy, Adel El Sayed Tawfik

In space, there is a lack of necessary legal frameworks. The lack of sensors is also an issue. Additionally, there is a need for better analysis to understand the phenomena affecting the globe.

The increase in the world's temperature caused by climate change will affect disease vectors. This will wreak havoc if it is not dealt with. The recent report from the IPCC brings worrying news. We are on a trajectory towards a 2.5-degree or even a 3-degree increase in temperature.

Genetically-modified organisms have great potential for solving global food issues. However, skepticism and a lack of understanding have prevented their widespread use.

Peace and stability in the world will depend on the attitude of people and nations towards science and technology, as well as inclusion and sustainability. The environmental issues facing us must be urgently dealt with. However, there is inadequate public understanding and political will. Time is of the essence.

Dr. Sébastien Candel provided a summary of the discussions from the cooperation in science and technology track. The sessions also dealt with the primary needs of the world. One major issue is global poverty. Developing countries should not follow the model of developed countries and instead adopt technologies and policies suited to local needs.

Consolidation of education at all stages is also a major issue. STEM education and the education of women in particular are essential for achieving sustainability. It is also important to encourage people to come back to their own country after being trained abroad.

With regard to government-industry-academia collaboration, open innovation, policies related to academic career paths, and the involvement of industry in research are valuable. There is a need for people to move out of their comfort zone and develop cross-sectorial

partnerships. Useful measures include the establishment of competitive clusters, dialogue between the public and private sector, and the creation of enabling environments. There are also obstacles to promoting collaboration such as mismatched needs between industry and academia. Setting shared goals, visions, and scenarios can promote collaboration. Compromise is also needed.

Candel, Sébastien

The major issues faced by the global community cannot be solved by any one country alone. International collaboration is essential and scientific diplomacy helps to promote this. Scientists as a global community speak the same scientific language, share the same analysis methods based on evidence and reasoning, look for truth and novel solutions, and are often involved in cross-border collaborations. They are an invaluable asset for the development of international links. Science, technology and innovation are an important tool for achieving the Sustainable Development Goals (SDGs). Science, technology, innovation and education have a central role to play in promoting sustainable development. Investment is needed to support scientific advances and innovation.

Dr. Hanoch Gutfreund presented the key messages from the science and technology and society track. The main focus of the discussions was on modern society and digitalization in all areas of society. The sustainability of modern societies depends on innovation. However, there are different types of innovation. Innovations that are in response to social needs rather than questions from nature require an innovation ecosystem, entrepreneurship, and political and public acceptance. Government, industry and academia all have their respective roles to play.

Some of the other key messages from the sessions include the need to foster a mindset of innovation, the importance of social sciences for promoting social innovation, the growing gap between perception and factual knowledge and the need for better scientific communication such as through science journalism, the role of education in promoting critical

Gutfreund, Hanoch

thinking, the importance of articulating the value of science and technology advances when engaging political leaders, and the difference between lobbying and science advising.

Dr. Motoko Kotani summarized the discussions from the ICT concurrent sessions. ICT is transforming society. It offers great potential, but also serious dangers and concerns. Trust and education around ICT are essential for tackling these concerns. The fostering of the next generation of leaders is also important.

AI is ubiquitous. We need to have a clearer understanding of AI from the perspectives of government, industry and academia. Governments need to understand the impact of AI and data, and provide adequate protections for citizen's privacy. Open data sharing will also be valuable. In addition, advances in quantum computing can overcome current limitations in computational systems. Dialogue with social scientists will be important for dealing with ethical questions related to AI.

As societies become more digitalized, cybersecurity will become an ever more important issue. Cybersecurity raises societal, technological and governmental challenges. The sharing of information on cybersecurity as well as cybersecurity insurance are important. All industries must be aware of the risks of cybersecurity and take the necessary risk management measures. Quantum computing will also give rise to new challenges. Additionally, it is necessary to nurture the next generation of cybersecurity professionals.

In big data, multidisciplinary research in cutting-edge areas is needed. Generation of data, filtering of data, quality of data, ownership of data, and incentivizes for data sharing are important issues for data-driven societies. It may be useful to set up an intergovernmental panel on big data to deal with these key issues.

Overall, the future looks promising if we share what we have learned and work together to create a better future. STS *forum* is the perfect venue for us to share and utilize our knowledge, and to take action.

Kotani, Motoko

Dr. Takashi Onishi presented the key messages from the social infrastructure concurrent sessions. The three sessions dealt with new transportation systems, smart and resilient cities, and advanced agriculture and food industries. All three areas are closely tied to the SDGs. Science and technology can bring about advanced development in social infrastructure and promote the achievement of the SDGs. Innovations in AI and ICT will transform such social infrastructure. A key question is how to provide equal access to social infrastructure and allow all people to lead comfortable lives.

As for specific discussions, with regard to new transport systems, it is important to use new technologies to correct the problems with current driving technologies, without giving rise to new problems such as safety or ethics. As for smart societies, how "smart" each smart city is depends not on the technologies they have, but the problems they face. Technological advances have boosted agriculture and food production. However, people are sensitive to what they eat, and one of the key issues is gaining public acceptance for foods produced by new technologies.

While the adoption of new science and technology can greatly improve our lives, they also produce problems of their own. It is essential that we understand deeply the lights and shadows of science and technology.

Dr. Marian Asantewah Nkansah expressed her gratitude, on behalf of the Future Leaders, to be able to participate in such a wonderful conference, as well as her personal thanks to The World Academy of Sciences and STS *forum* for her nomination and sponsorship. The ability to interact and hear the views of the various high-profile participants of STS

Onishi, Takashi

Nkansah, Marian Asantewah

forum, including many Nobel Laureates, is truly inspiring for young scientists. In closing, Dr. Nkansah shared a quote from former Secretary-General of the United Nations Kofi Annan that one is never too young to lead and never too old to learn.

Dr. Oscar Grånäs stated that STS *forum* is an excellent opportunity to draw on the experience of senior scientists, and established leaders in politics and industry. He believed that the role of Future Leaders in academia is to continue the progress of society. To that end, greater outreach is needed, particularly to younger people. Younger people must also be provided with the skills to avoid false perceptions. Lastly, Dr. Grånäs emphasized the importance of government-industry-academia communication, transparency and trust.

Q&A Session

One participant commented on the potential of research into natural products, for example for insights into new medicines. He also stressed that the transport sector is undergoing a revolution, and pointed out the potential for new modes of international travel and transport.

Dr. Collins agreed that there is potential in scientific research on natural products, noting that aspirin is acetylsalicylic acid, which is found in willow trees.

Another participant commented on the need to better integrate a wider range of disciplines, including social sciences, politics, and natural sciences, for dealing with global environmental issues such as climate change.

Closing Remarks

Dr. Gruss reemphasized the value of government-industry-academia collaboration. In particular, there is still too little interaction between industry and traditional academic institutions. Greater industry-academia collaboration is needed but the autonomy of academic institutions must be maintained. As for governments, politicians represent and enact the will of the people, and scientists need to communicate more effectively with the public to gain their understanding for and acceptance of science and technology.

Grånäs, Oscar

Energy
Renewable Energy and Power Grid

[Chair]

Abdul Hamid, Zakri, Joint Chairman, Malaysian Industry-Government Group for High Technology, Malaysia

[Speakers]

Ashby, Steven, Director, Pacific Northwest National Laboratory (PNNL), U.S.A.

de Sain, Pascal, President, DSM Advanced Solar, Netherlands

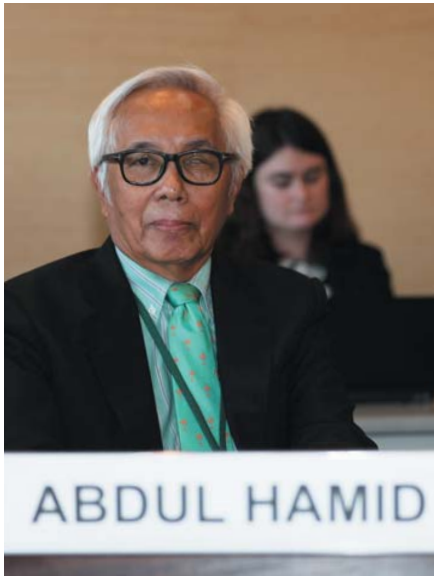
Hashimoto, Kazuhito, President, National Institute for Materials Science (NIMS), Japan

Kelly, Michael Joseph, Emeritus Prince Philip Professor of Technology, Department of Engineering, University of Cambridge, U.K.

Platt, Glenn, Research Program Director, CSIRO Energy, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia [Future Leader 2017]

Yeh, Nai-Chang, Professor of Physics, California Institute of Technology (CALTECH); Fletcher Jones Foundation Co-Director, Kavli Nanoscience Institute, U.S.A.

Opening Remarks



Chair: Abdul Hamid, Zakri

The chair opened the session by echoing remarks from the opening plenary on a prediction of the content of the statement to be issued by the Intergovernmental Panel on Climate Change. He predicted that the statement's content would include that climate change is real, that we are feeling its impact, and that it will only get worse. Renewable energy is thus crucial to move forward.

The session speakers were then invited to offer comments. It was noted that the US Department of Energy is investing in the country's energy future, with the Pacific Northwest National Laboratory focusing on increased electrification and a reliable, affordable power grid. The current US grid was a marvel, but is

aging while facing unprecedented ET, OT, and IT demand. The Grid Modernization Laboratory Consortium tackles creating a resilient, reliable, flexible power grid.

The discussion then turned to the transformation of energy business to sustainability and purpose in combination with making money. We cannot be successful in a world that fails. Energy subsidies, including on renewables by feed-in tariffs, should be replaced by transparent carbon pricing mechanisms. Another challenge is low deployment of innovation in PV; much technology is ready and on the shelf but not being deployed. Yet another issue is potential non-circularity of renewables like PV and wind.

The next topic was the efforts by the Japanese Government for smart grid usage for increased renewable energy, with investment accelerated from 2012 with the FIT policy. In the government's vision for 2030, renewables are expected to account for 22-24%. One of the measures against energy instability is virtual power plants (VPP), cloud-based distribution of power, as well as energy resource aggregation business. The government has started a 5-year demonstration project for VPP.

Following this, it was noted that by 2050 the world's population will be concentrating in megacities and fossil fuel use will still be prevalent. Per capita energy use in cities has been flat recently, with energy savings offset by wider use. Energy demand grew by 40% between 1995-2015, in conjunction with more people escaping poverty and correspondingly higher energy usage. Fossil fuel use will increase at a faster pace as renewables cannot keep up with demand.

Next, the speakers turned to Australia, a leader in transitioning its energy system towards renewable and decentralized energy. The country has the highest penetration of distributed solar and the electricity sector is on track to meet the Paris Agreement commitments. Renewable energy is growing and will eventually replace fossil fuels. At the same time, Australia recently had a major blackout, has some of the most expensive electricity in the world, and widely-held concerns about reliability. Major issues include a popular misconception that renewable energy has hurt reliability when the opposite is true, and a lack of planning for how to navigate the transition ahead.

Finally, the speakers noted that one major issue is energy storage, with ideal traits including high storage capacity, fast charging and discharge rates, affordability, accessibility, and environmental consideration. Caltech used techniques to quickly grow quasi one-dimensional

nanostructures that have excellent conductivity and connectivity. Industry has taken notice and Caltech is scaling up the development. The speakers also noted that education is needed to train the next generation and society to consider the environment.

Discussion

Following the opening remarks, a group discussion was held. The participants covered diverse topics including flexible demand response, the need for the financial community to understand technology and uncertainty, unsustainable FITs and long-term policy changes, social equity issues, creating a balanced renewable mix, and energy efficiency.

Participants also discussed geographical differences between countries and the need for focused policies, that richer countries can help developing countries progress, and the differing targets of policies of different countries.

Another discussion yielded agreement on a number of principles including that renewables are essential for tackling climate change, that ambitious climate change targets need to be set for renewables that also take into account different countries, and that close cooperation between academia and industry is important.

Another discussion revealed different situations between countries in terms of fossil fuel use, that economic issues are often more daunting than technological issues, questions about how serious governments are about renewables, issues surrounding nuclear power plants, and the need for development of technology such as for hydrogen fuel that does not produce greenhouse gases.

In addition, the participants noted that the energy transformation will take decades, with discussion about energy for the poor and renewables as a solution for it, the life cycle of renewables and how to conduct fair comparisons of the costs involved, changes necessary in the power market to accommodate renewables such as distributed dispatching, reliability and new batteries, the role of smart grids that are changing how customers and producers interact, and that renewables are making enormous progress such as with hydrogen fuel. The ideal system would be carbon neutral with increasing use of renewables based on the pace of technological innovation.

Energy
Net-Zero Emissions

[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]

Atrey, Milind Diwakar, Institute Chair Professor, Mechanical Department, Indian Institute of Technology (IIT) Bombay, India

Hagen, Tim van der, Rector Magnificus/President, Executive Board, Delft University of Technology, Netherlands

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

Pecresse, Jerôme, President and CEO, GE Renewable Energy, France

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

Shimizu, Ryosuke, Executive Vice President, CSO and Director of Corporate Planning Division, Chiyoda Corporation, Japan

Opening Remarks

Chair: Nathwani, Jatin

The chair opened the session by emphasizing that radical innovation is urgently needed for a net-zero emissions future. However, the current state of innovation in the energy sector is incremental, not keeping up with our energy consumption which will double within the next 3-4 decades. We need innovative solutions to meet the twin challenges of a low-carbon world combined with equitable energy. Paths leading to net-zero emissions include primary energy shifts from high carbon to low carbon and then to renewable energy, energy storage along multiple paths to counter uneven global distribution of renewable resources, and electrification of the economy.

The session speakers were then invited to offer comments. It was argued that our primary focus should be on functionality. Thus, the energy revolution can be defined as a problem of logistics, including storage, transport, and conversion. We need to think of strategic processes, such as useful applications of waste and creation of useful byproducts, as well as efficiency and breakthrough new technologies.

The discussion then turned to measures in Japan for reducing CO_2 emissions. Japan's New Energy and Industrial Technology Development Organization (NEDO) is making dedicated efforts to overcome the difficult hurdles to increasing use of renewables. NEDO's work includes innovative wind power, utilizing hydrogen for a new system of power supply coordination, and low carbonization efforts especially through hydrogen toward creating a Hydrogen Society.

The next topic was India's innovative efforts for net-zero emissions and reducing greenhouse gas emissions. India's growth rate requires increased energy, so it is making steps toward a renewables target of 175 GW by 2022, Prime Minister Modi is a leader in the International Solar Alliance, and the rail network is being electrified. The Indian Institute of Technology Bombay has been supporting India's efforts, including taking a cryogenic approach for truck transport.

It was then noted that renewables are already mainstream and have become the cheapest form of energy vs. conventional sources, and it was argued that the next revolution for energy will be dispatchable green electrons. New players are investing in renewables and new segments of the market are opening. However, we need more innovation to keep up with increased demand, including digital solutions, automation, and more investment in grid hardware and software.

Chiyoda Corporation's work was then discussed, including its efforts to tackle climate change for net-zero emissions. Hydrogen will be the great connector of different sectors such as electric power, transport, industry and private in the future. Renewable energy will be introduced to the power sector first, and then electric power and hydrogen will follow as energy carriers to couple the sectors. However, issues include uneven distribution of solar, wind, and rain precipitation in terms of time and geography, and for this, hydrogen presents various solutions for storage and transport. Chiyoda has developed liquid organic hydrogen carrier technology named SPERA Hydrogen and is preparing a NEDO-funded demonstration project to be operated in 2020.

Finally, the topic was national action on greenhouse gas reduction in Indonesia. Efforts include environmentally-friendly agriculture technology, including improving irrigation networks and biogas. The country has constructed wind and solar power plants as well as electric mass transportation. It also focuses on the use of biofuels, wastewater system improvement, and application of waste disposal in environmentally-friendly processes.

Discussion

Following the opening remarks, a group discussion was held. One discussion was on industry approaches and needs, financing and investment, new technologies, and long-term needs. Another discussion focused on energy efficiency, especially on optimizing energy use in buildings such as through better materials that look toward the future, and creating regulations that would make this obligatory.

The discussion also encompassed reducing methane emissions, which can be thought of as a low-hanging fruit, the feasibility of carbon sequestration, and bridging technologies and energy market changes toward energy of the future especially in countries that depend on fossil fuels.

A further discussion was started by asking the following questions: a) What does every country need to do to accelerate and disseminate technology innovation? b) What is the role of global financing and what kinds of financial networks do we need? c) How can we

integrate wisdom between industry and academia to tackle the energy problem? Regarding question a), it was argued that modern nuclear reactor technology that is affordable, safe, reliable, and does not pose nuclear weapon relevance is important. PV and wind technologies are affected by supply and demand. At the same time, they are intermittent. So, we need to approach these technologies from a system optimization perspective. This will also help reduce cost. A relevant issue is how we can achieve the goal of complete elimination of the fossil fuel dependence. This can be done through thermal power generation along with CCS or PV and wind with energy storage technologies. It was noted that efficiency increase in thermal power generation can have an enormous effect on CO_2 emissions. Regarding question b), the discussion centered around the 3Es = Energy, Environment, and Economy. In general, each country has its own priorities amongst the 3Es. The discussion then moved on and it was stated that we need to price the carbon in order to address the issue of importance and the cost of energy. We need to monetize the environment. Each country should establish its own roadmap: whether its energy mix will depend on biomass or geothermal, or natural gas, etc. The developing world can capitalize on technology from the developed countries. For this, we need international cooperation for technology transfer. Financing must be done freely by everyone, including governments and the private sector. Regarding question c), it was concluded that academia is very important in the race to decarbonize the energy mix. Academic research in collaboration with industry can help invent disruptive technologies.

Another discussion was on how individuals should be responsible for their use of renewables, recycling and the need for longer lifetimes of components, and responsibility at an individual level such that people adopt efficient devices and have an overall understanding of their own use of energy. The final discussion was on the necessity of a technical approach to energy such as through microgrids and utilizing ICT technology to communicate, the importance of hydrogen, and making commercially viable technologies such as CCS.

Energy

Future Prospect of Energy Mix (Nuclear, Oil and Gas, etc.)

[Chair]

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

[Speakers]

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

Hosaka, Shin, Deputy Commissioner, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI), Japan

Mutoh, Jun, Representative Director and Executive Vice President, JXTG Holdings, Inc., Japan

Semeria, Marie-Noëlle, Chief Technology Officer, Research & Development Division, TOTAL S.A., France

Svasti-Xuto, Wittawat, Chief Technology Officer, PTT Public Company Limited, Thailand

Xiaoping, Yang, Chairman and President, BP China, China

Opening Remarks

The chair opened the session by describing extraordinary changes in energy research and advancement in the last 10 years, including in the dollar per kW of solar power, wind power capacity, plummeting oil and gas production costs, and gas turbine heat rates. We are on the cusp of major improvements in batteries beyond lithium ion, lowering emissions and waste, fusion deployment, and AI and machine learning with oil and gas application for 3D seismic data. International partnerships and working with communities represent important opportunities for the future prospects of energy mix.

Chair: Dabbar, Paul

The discussion then turned to the relationship between society and energy. Energy mix must be based on a solid foundation of safety and the 3Es of energy security, economy, and environmental conservation. Renewable energy is increasing at a pace that is not fast enough, so the key to our future is innovation. Japan aims to utilize its technology and expertise to reduce CO_2 and make contributions to energy around the world.

The participants then discussed energy mix, innovation, and Japan. Japan's recent energy situation is heavily influenced by its approach to nuclear power following the Fukushima accident. The Japanese Government introduced an FIT policy in 2012 which yielded high costs, so the basic energy policy was revised this July. Now Japan is focusing on public-private cooperation, new technologies, low-cost renewable energy, restarting nuclear power plants, and strengthening human resources.

The discussion then turned to the role of renewables as the fastest growing fuel source in meeting increasing demand in developing countries that have rising economies and increased energy demand as people climb out of poverty. China is the largest source of growth, adding more renewables than the entire OECD combined. BP China is dedicated to growing its energy business without an increase of carbon emissions, including through its RIC framework.

Another company, Total S.A., is a global integrated energy and electricity leader that has three responsibilities: developing a low carbon energy mix, strategic cooperation to create a new generation of battery, and speaking up about the slow pace of renewable energy in meeting primary energy demand. The company has also acquired subsurface seismic information, and is tackling artificial intelligence research solutions with Google.

There was then a discussion on the reality of the persistence of LNG and the importance of Life Cycle Analysis as the basis of comparison for emissions, with the point being made that the best way to address the energy mix realistically is increasing efficiency. Saudi Aramco works with auto makers to improve the efficiency of transport, explores new technologies to address challenges such as carbon, takes note of technologies like carbon capture that have not received enough attention, and looks to the future of power represented by distributed generation.

Thailand's PTT Public Company Limited aims to fulfill the SDGs through provision of affordable, clean renewable energy. Its focuses include biogas, technology for reduced cost, and improved access. Placing the two most critical aspects of energy mix as accessibility and GHG reduction, PTT contributes to development in rural areas in Thailand, educates people on strategic use of energy, and became an affiliate of the Energy Web Foundation.

Discussion

Following the opening remarks, a group discussion was held. The first discussion focused on technology and public policy, including that energy efficiency and storage are important especially for the industrial sector. There is risk with targets for public policy not being informed by scientists. Technology should drive the process, and allow for flexibility in policy based on different locations and countries.

Another discussion was on cost impact of various renewable energies and the need to look beyond just cost when adopting technologies.

A third discussion yielded a consensus that there needs to be a diverse mix of energy rather than strong proponents of just one type, challenges of cost-efficient CCS, the need for more science and research on old chemical processes, the importance of distributed generation for developing remote communities, and how countries dependent on oil and gas can transition to our new energy mix future.

There was also a lively debate on the extension of previously disregarded technologies such as direct air capture, hydrogen which has not received enough attention outside Japan, allowing competition of technologies to drive carbon efficiency, CO_2 neutrality, and finally proposals of energy mix scenarios that yielded a consensus that we should be ready to look at all forms of energy and not believe that just one form of energy will solve everything.

The last discussion was on small modular type hydropower facilities which have low environmental impact and aid agriculture, that some countries now run such facilities and are exporting those technologies to other countries, the importance of nuclear power and the need to change the public perception of it, and utilization of block chain to distribute power more efficiently and effectively.

Life Sciences
Genome Editing

[Chair]
Hacker, Jörg, President, German Academy of Sciences Leopoldina, Germany

[Speakers]
Fire, Andrew Zachary, Professor, Departments of Pathology and Genetics, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2006 (Physiology or Medicine)]
Hayashizaki, Yoshihide, Program Director, RIKEN, Japan
Leptin, Maria, Director, European Molecular Biology Organization (EMBO); Professor, Institute for Genetics, University of Cologne, Germany
Nakagama, Hitoshi, President, National Cancer Center, Japan
Pei, Duanqing, Professor and Director General, Guangzhou Institutes of Biomedicine and Health (GIBH), Chinese Academy of Sciences (CAS), China
Zerhouni, Elias Adam, Medical Doctor; former Director, National Institutes of Health (NIH), U.S.A.

Opening Remarks

Chair: Hacker, Jörg

The chair began the session by framing the discussion around four key topics. First is the need for more public discussion on genome editing and the various applications of this technology. Second is regulatory issues related to new breeding technologies. Third is personalized medicine. Fourth is increasing the productivity of agriculture in a sustainable way.

Next, the speakers discussed TALE and CRISPR technologies. There are obviously lights and shadows to such technologies. There has been much emphasis by the public on the shadows, so it is necessary to also raise awareness about the benefits. It is also necessary to ensure that such technologies are handled responsibly and safely.

The speakers then spoke about advances in genome editing technologies as well as the related issues. For example, genome editing has become a powerful research tool. In addition, next year, Japan is set to approve the editing of the genomes of germ cells for assisted reproductive therapy. At the same time, there are three main issues: the ethical aspects, potential off-target effects, and the unidentifiability of the genome-edited cell or organism.

Another subject of discussion was the ruling of the European Court of Justice that genome-edited crops should be subject to the same stringent regulations as conventional genetically modified organisms. This ruling was unfortunately based on the process used to create such organisms, which was deemed to be similar to the creation of genetically modified organisms with older technologies, rather than the resulting organism, which is more similar to organisms created by standard mutagenesis. However, it is understandable as the public lacks the scientific knowledge to consider these issues rationally. More needs to be done to educate the public and also to prevent the publication of questionable science.

The speakers then turned to genome editing in cancer treatment research. A number of promising new cancer treatment methods have emerged. These include molecular-targeted treatment, checkpoint inhibitor immunotherapy and CAR-T treatment. The speakers also spoke about detection and treatment of hereditary cancers, and the use of genome editing to develop new modalities. Protection levels for the risk of genetic interventions in different contexts should be discussed from clinical, ethical and social points of view.

The use of CRISPR technology to treat rare genetic diseases was also raised. There are four main issues that must be overcome: securing adequate funding for basic research, developing the technology platform in a transparent way, establishing appropriate regulations, and incorporating CRISPR technology in hospital care. If these issues can be solved, CRISPR will surely be a very cost-effective means of addressing rare genetic diseases.

Lastly the speakers took up the ethical questions raised by genome editing and public perception. Genome editing raises new ethical concerns compared to past genome-related research. At the same time, the public's trust in science has declined in recent years. Scientists must work to regain the public's trust. One way is for the scientific community itself to address the question of risk accountability.

Discussion

A group discussion was then held. The participants first dealt with public engagement and trust. Scientists need to develop more effective communication strategies. The benefits and risks of a technology should be framed in a way that is relevant and accessible to the public. The involvement of social scientists will be useful. The press should also be engaged. In addition, it is important for scientists to also acknowledge the negative aspects and limitations of technology; in addition to our responsibility to communicate accurately, this type of narrative will help maintain credibility.

The participants also discussed how there will likely be continued interaction and possibly tensions between law and science in the future. Scientists must also help keep lawmakers informed. Furthermore, they must make more of an effort to educate the public and raise their science literacy. The participants also noted that one of the reasons for the skepticism among the public towards science is the existence of well-funded movements against science.

They then discussed the need to maximize the precision of genome editing, which will increase the safety of this technology. In addition, the participants discussed the possible

interest in (and/or need for) identification of gene-edited individuals, while noting that these may also raise ethical questions about the treatment of gene-edited individuals and non-gene-edited individuals. The potential eugenic dangers of CRISPR technology were also noted. Another subject was the possible non-medical applications of CRISPR technology. Besides medical uses, CRISPR will also be used to increase food production, and could offer value in such diverse applications as modifying algae to enhance carbon sequestration.

Life Sciences
Healthy Aging and Preventive Medicine

[Chair]

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

[Speakers]

Di Carlo, Dino, Professor and Vice Chair, Department of Bioengineering, University of California, Los Angeles (UCLA); Director of Cancer Nanotechnology Program, Jonsson Comprehensive Cancer Center, UCLA, U.S.A.

Olsen, Dag Rune, Rector, University of Bergen, Norway

Takahashi, Masayo, Project Leader, Laboratory for Retinal Regeneration, RIKEN Center for Biosystems Dynamics Research, Japan

[Voluntary Speaker]

Sindelar, Robert, President, Global Drug Commercialization Centre (GDCC) – Chengdu, China; Global Vice President, GDCC-Worldwide, Canada

Opening Remarks

The chair opened the session by pointing out the aging of societies and the consequences thereof. Life expectancy is increasing worldwide. The aging of societies increases the incidence of age-related diseases, such as cancer, osteoporosis, hypertension and Alzheimer's. It also gives rise to new socio-economic issues such as mobility and housing. The overall challenge is to enable people to lead healthy lives for longer. Both the medical and the socio-economic issues associated with aging need to be addressed.

Chair: Wallberg, Harriet

Following the chair's remarks, the speakers discussed age-related issues in Japan. Japan has the highest life expectancy in the world and is therefore at the forefront of dealing with such issues. Japan is prioritizing regenerative medicine, such as cell transplantation, as one means of dealing with them. Ophthalmology is a particularly promising area for regenerative medicine. In addition, as societies age, we need to redefine what it means to be healthy, rather than seeking perfect health.

The speakers then turned their attention to diagnostics. Advanced diagnostics approaches could have a transformative impact on how diseases are defined and detected, enabling earlier intervention. Two enabling technologies are particularly promising: quantum diagnostics and ubiquitous health sensors. These technologies will also raise questions around access to treatment, balancing medical and behavioral interventions, regulations, data privacy, medical literacy, and public acceptance.

The next topic of discussion was the high cost of new treatments and personalized medicine. Steps must be taken to reduce these costs, especially in the case of chronic diseases. Treatments must also be considered at the community-level. The speakers also touched on the promise of targeted therapies, as well as the emergence of treatment-resistant diseases. Perhaps multi-target therapies may be more effective than single-target therapies.

Next, the speakers discussed the complexity of promoting healthy aging. For example, epigenetic studies show that healthy aging needs to be thought about not only when a person reaches old age, but throughout their life. The definition of "healthy aging" must also be reconsidered. There are many different components, such as healthy sight aging, healthy muscle and joint aging, healthy cardiovascular aging, and healthy brain aging. Coaching can also promote the right behaviors for healthy aging.

Discussion

The participants then held a group discussion. They first examined the structure of the healthcare system and the need perhaps for more geriatricians. At the same time, healthy aging must be looked at in the context of people's whole lifespans, so perhaps more of other types of physicians may be needed as well. Mobile and out-patient solutions for geriatric care should also be considered. In addition, the participants noted the need for a multi-disciplinary approach to providing care for the elderly. It is important to break down barriers between different medical fields and promote more collaboration.

Another topic of discussion was the importance of early detection or prevention of diseases for healthy aging. This is a highly cost-effective way to deal with health issues and healthcare systems should reimburse people for disease prevention. Medical treatments must

not only be safe and effective, but also cost-effective. The value proposition of medical treatments should be reexamined as the current payment models are unsustainable. More government support and new funding schemes are required. There should also be social support systems for the elderly and AI has the potential to assist with this. All parts of society, including businesses, must adapt to the aging of societies and support the elderly. Social interactions can also promote healthy aging. For example, having senior citizens get involved in childcare can address the shortage of childcare of workers while also providing the elderly with healthy social stimulation.

In addition, the participants believed that the definition of "health" should be redefined, especially as technological advances allow people to overcome conditions that were previously seen as impairments. They also touched on new technologies that provide greater access to diagnosis and medical treatment, such as self-diagnosis tools, DNA analysis services, and telemedicine and the push towards individualized medicine. Furthermore, the participants discussed behavioral interventions, such as educating people about healthy habits and coaching to encourage the right behaviors.

They then took up changes to family structures as a result of the aging of society, and different cultural attitudes that affect how communities perceive and deal with healthy aging. Another subject was the risk of aging exacerbating gender disparities, as women are seen as the primary caregivers in many societies.

Finally, the participants emphasized the need to maintain health science approaches and not opportunistic business approaches.

Life Sciences
Advanced Medicine and Bioengineering

[Chair]

Doyle, Frank, Dean, Harvard John A. Paulson School of Engineering and Applied Sciences, U.S.A.

[Speakers]

Hara, George, Chairman, Alliance Forum Foundation; Special Adviser to the Cabinet Office, Prime Minister of Japan; Intergovernmental Ambassador Extraordinary and Plenipotentiary to the United Nations, Japan

Hasegawa, Mayumi, Head, Clinical Pharmacology Strategy Japan, Bristol-Myers Squibb Company, Japan [Future Leader 2017]

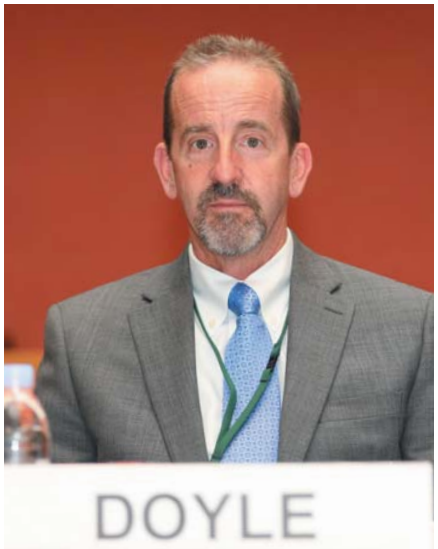
Mohr, Catherine, Vice president of Strategy, Intuitive Surgical, Inc., U.S.A.

Vallance, Patrick, Government Chief Scientific Adviser, Government Office for Science, U.K.

Yamamoto, Tadashi, Director, RIKEN Center for Integrative Medical Sciences; Professor, Cell Signal Unit, Okinawa Institute of Science and Technology Graduate University, Japan

Ying, Jackie Y., A*STAR Senior Fellow, NanoBio Lab, Singapore

Opening Remarks



Chair: Doyle, Frank

The session opened with remarks from the chair. Biology largely centers on the principle of "sense and respond," and discussions of advanced bioengineering inevitably involve modalities based around these two pillars (e.g., detection, diagnostics, and treatment). The suitably wide range of the speakers was pointed out (from academic research to private sector translation to government policy).

The speakers first talked about alternative approaches to anti-biotics for fighting anti-microbial resistance (AMR). One example is the development of new nanomaterials for use as antimicrobial agents that would not have drug

resistance issues. Another is diagnostics and tests for screening for various bacteria infections in a multiplex manner. In addition, the speakers noted that rapid and more cost-effective diagnostics are emerging, such as inexpensive paper-based assays for detecting infectious diseases. The use of human primary cells for in vitro toxicology is also making drug screening more efficient.

Next, the speakers discussed some of the cutting-edge research being conducted at RIKEN. RIKEN is leveraging the huge amounts of data accumulated by hospitals to understand and treat various genetic diseases. It is also advancing research on cancer immunotherapy. For this, the cancer landscape needs to be further clarified, including through the use of big data.

Value-based healthcare was also discussed. In recent years, improvements in life-expectancy seem to be leveling off, despite advances in science and technology. This is perhaps because of the high costs of treatments and unequal access to medicine. A systems-based approach is needed to achieve value-based healthcare. Though it may seem counterintuitive, some technologies, such as surgical robots, that are well-integrated into the medical system, provide direct and indirect value that outweighs the initial high investment cost.

The next topic of discussion was cancer treatment. Pediatric cancer has been somewhat overlooked compared to adult cancer. Various solutions have been initiated to correct this situation such as master protocols and pragmatic trials to accelerate the development of treatments or the use of bio-markers to detect cancer sooner. More generally, the speakers touched upon the need for scientists to interact more actively with society to maximize the impact of their research and the importance of government-industry-academia collaboration.

The speakers then discussed the role of governments in combatting AMR. Governments should promote cohort studies and build trust around them by making the results openly available. They should also establish smarter regulations, help scale new technologies, and ensure that healthcare systems can implement new techniques. More basic science is also needed. Overall, if governments make smart decisions and introduce the right incentives, they can promote the right scientific advances and produce effective new medical technologies that are accessible for all.

The speakers also imagined a world where everyone can lead healthy lives until the very last moment of their life. To realize such a world, there needs to be not only technological

innovations but also policy innovations, such as new frameworks for accelerating drug approval while still maintaining safety or those for incentivizing research into understanding and treating rare diseases.

Discussion

Afterwards, a group discussion was held. The first subject of discussion was methods to accelerate the application of new technologies that would benefit the public. These include establishing mechanisms to incentivize pharmaceutical companies to support research that may not provide immediate or direct benefit for the companies, ways to facilitate the clinical translation of research, and cost-saving measures. It is important to support innovative research and spinoff companies, besides encouraging early investment from pharmaceutical companies to prevent promising biomarker research from falling into the so-called Valley of Death. In addition, new trial designs and novel regulatory frameworks could be useful, as well as mechanisms to finance new treatments.

The participants also emphasized the importance of fundamental research and the need for long-term sustainable funding for it. In addition, the participants considered the combination of large sets of multi-omics and clinical data and its use for precision medicine. They also called for better data-sharing techniques, including publishing dark data as well as negative data. This in turn raises the issue of patient-data protection, and questions such as who owns the data and what would be the highest level of data that could be implemented.

It is important to have appropriate regulations to ensure that the right data are opened up to the right groups. Furthermore, there is potential for confusion if the public has access to data that contain false correlations.

The participants then considered value-based medicine, the definition of value, and the need for a systems-based approach to medicine. They also touched upon the use of precision medicine to treat pediatric illness. Finally, the participants noted the potential benefits of harmonizing countries' regulatory frameworks, and different schemes that different countries have towards supporting startups and entrepreneurship in advancing medicine and medical technologies.

Engineering and Innovation
Industrial Innovation

[Chair]

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

[Speakers]

Amano, Hiroshi, Director and Professor, Center for Integrated Research of Future Electronics, Institute of Materials and Systems for Sustainability, Nagoya University, Japan [Nobel Laureate 2014 (Physics)]

Arzt, Eduard, Scientific Director and Chairman (CEO), Leibniz Institute for New Materials (INM), Germany

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

Kanda, Masato, Deputy Director General, Budget Bureau, Ministry of Finance, Japan; Chair, Corporate Governance Committee, OECD

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

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

Opening Remarks

Chair: Kirloskar, Vikram S.

The Chair opened the session by speaking about the human element in pushing innovation within organizations, and the approach of connecting employees with higher objectives such as caring for the environment, the importance of environmental goals such as eliminating vehicle emissions and achieving a recyclable society, aiming for zero-emission plants and supply chains in industry to achieve total carbon reduction, and other means to galvanize innovative approaches amongst businesses to promote and work towards a better world for all.

The session speakers were then invited to offer comments. Discussions began with how to establish a sustainable, safe, and secure society utilizing the Internet of Energy (IoE), challenges with electric vehicles and drones related to battery life and charging time, and the establishment of new wireless energy grids and graduate programs to raise a future generation of scientists.

The subject of micro processing density was then brought up, and the transformative impact it has had on information technology and the electrical grid as well as the remarkable opportunity it presents for future innovative solutions. The penetration of renewable energy globally, the resurgence of nuclear energy via utilization of new manufacturing technologies, the growth of Internet of Things (IoT) enabled devices and the decentralization of new energy grids were also noted.

Another subject raised was the combination of theory and practical application in terms of energy storage materials. Energy inevitably produces side effects, and one of the challenges of science is how to minimize them to protect health and safety. The cost of electricity has risen to promote new developments of renewable energy. However, in the long run these benefits will outweigh the short-term increase in cost. These political and financial challenges need to be overcome by industry, government, and the public. Issues related to IP, patenting, and justifying research are also hurdles for the academic community.

Next, the speakers discussed the driving force of sustainability behind industrial innovation. Control of the total energy flow is the goal of sustainability. Increasing choices of energy sources will create more flexibility for utilization in different applications, and collaboration between the scientific community, government, and industry is essential to achieving this.

The government's role in industrial innovation was also raised. Motivating employees to work towards sustainable goals and raising the next generation of leaders is an ongoing challenge. Employees are facing different challenges in terms of skills they must have to be competitive in the job market, and there is a strong need to move technological advances from academic institutions to industry more speedily. New technology approaches between government-funded agencies and private companies are one way to achieve this.

The speakers also addressed ways to promote innovation by governments despite the risks attached to market distortion, moral hazards, free riders as well as fiscal constraints. To enhance productivity of S&T, laboratories must be opened across institutions, countries

and disciplines and the shift to interdisciplinary and international research. Fiscal incentives, organizations of platforms for collaboration between academia and industry, effective regulatory measures, and appropriate sharing of roles and responsibilities can help achieve more effective and dynamic innovation.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon accelerating from innovation to invention, societal value creation, balanced government/industry/academic collaboration, investment in education for the next generation's leaders, and the role of startup ecosystems. There was also discussion of IoT and IoE, education for IoT and IoE, and energy policy.

The participants then highlighted the emergence of electric vehicles and challenges around energy storage and charging, increasing wind power utilization in Japan, usage of new and innovative nuclear technologies, and smart energy management.

Sustainable goals, the challenges of developing countries in creating energy sources which are also sustainable, and the difficulties of creating energy policies which consider business, government, and academic considerations were also discussed. There was also discussion of the role of government in innovation as a facilitator in determining financial output goals and providing funding.

Lastly, the importance of pushing researchers to become better communicators for non-academic audiences, the mismatch between financial and societal goals within the Fourth Industrial Innovation context, and disseminating information around sustainable goals to increase understanding amongst the public was raised.

Engineering and Innovation
New Engineering Technologies

[Chair]

Hastings, Daniel, Director, Singapore-MIT Alliance for Research and Technology (SMART), Singapore; Professor of Aeronautics & Astronautics, MIT, U.S.A.

[Speakers]

Chantra, Wirach, Acting for Governor and Deputy Governor Industrial Services, Thailand Institute of Scientific and Technological Research (TISTR), Thailand

Chen, Wenchi, Chairman and President, VIA Technologies, Inc., Taiwan

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

Feringa, Bernard, Jacobus van 't Hoff Distinguished Professor of Molecular Sciences, Stratingh Institute for Chemistry, University of Groningen, Netherlands [Nobel Laureate 2016 (Chemistry)]

Fujii, Teruo, Executive Director, Vice President and Professor of Institute of Industrial Science, The University of Tokyo; Japan

Newman, Dava, Apollo Program Professor of Astronautics, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology (MIT); Faculty Member, Harvard-MIT Health, Sciences and Technology, U.S.A.

Chair: Hastings, Daniel

Opening Remarks

The Chair opened the session by speaking about several engineering developments over the past century which have had a significant influence on mankind including mass electrification, the development of clean water supplies, air conditioning, air transportation, and space technology. He then commented on how new technologies will change our lives as we know them and require integration into our existing systems. He concluded his comments by stating that new technologies in the field of bionano, Internet of Things, medicine, and space research would need to be developed with sustainability in mind going forward.

The session speakers were then invited to offer comments. Discussions began on the topic of information technology and the fact that human consciousness is now shifting from the physical to the digital world, exemplified by technologies such as virtual and augmented reality. It was noted that these changes would have a massive effect on society, and that further, new developments in semi-conductor technology, advanced wireless networks, blockchain, and AI would help lead mankind towards a new digital world.

The subject of the negative aspects of science and technology was then brought up such as adverse weather events due to global warming. Comments were made around sustainable systems and technologies such as renewable energy and electric vehicles being required to combat such issues, however it was noted that technology alone cannot solve these problems. It was added that government, society, and business's input and efforts to create a sustainable society was also essential to achieving these goals.

Another subject raised was around education and raising the next generation of leaders in science. Future technologies are set to arrive in the coming decades including alternative energy systems and new infrastructure and agriculture technologies amongst others, which will need engineers who can develop these innovations of tomorrow. A comment was made around the science community needing to re-think their research culture to promote young researchers, and for industries and government to reconsider how they invest in economies and the next generation of scientists.

Next, the speakers discussed tissue formation and iPS cell technology developments which could have future applicability to cell and disease research. The use of molecules for information processing, such as with regard to specific genes and strands of nucleic acid for disease diagnostics was also brought up. One of the important exercises for the science community is to now think of future forms of devices and means to process information which could be energy efficient and have a low impact on the environment.

Current and future trends in the medical field was also raised. Trends show that the global market for medical technologies will grow exponentially in the coming years. These include but are not limited to the Internet of Things and its effect on continuous monitoring of patients, mobile connectivity, and others. To make sure the quality of such technologies is reliable, ample testing, standardization, and accurate IT system measurement is required.

The speakers then addressed interplanetary exploration. Human bodies are massively affected by the effects of being in space, such as by radiation. Further studies have shown that mental cognition can be affected as well as gut bacteria and gene expression. These studies will help further our understanding to create an eventual mission to mars. RNA and DNA sequencing, advanced closed loop life systems, bio-regenerative systems and combating the spread of false information as areas requiring further research in the field of space exploration were also discussed.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon the speed and scale of technological change, the importance of utilizing new technology in education, and delivering cheap energy on a sustainable basis. There was also discussion of KPIs and the social value of new technologies and defining quality of life and its context within new technology development.

The participants then highlighted new engineering technologies such as self-repairing and self-cleaning materials, biotechnologies, human-machine interface such as in the form of smart pills, and wearable and implantable tech. Cost accessibility and affordability of technology, ethics and the benefits of technology, and public trust in science and technology

were also discussed. There was also discussion of energy and climate change, data security, medical research, and communication between scientists and politicians.

Lastly, analog environments, multi-disciplinary approaches to space exploration, medical effects on the human body in space, mankind's quality of life on other planets, and teleportation technologies were discussed.

Engineering and Innovation
Robotics and Society

[Chair]

Sankai, Yoshiyuki, Professor/Executive Research Director, Center for Cybernics Research, University of Tsukuba; Program Manager, The ImPACT Program hosted by the Cabinet Office of Japan, Japan Science and Technology Agency (JST); Founder/CEO, CYBERDYNE, Japan

[Speakers]

Chang, Yen-Chung, Manager & Deputy Division Director, Service Robot Department, Intelligent Robotics Technology Division, Industrial Technology Research Institute, Taiwan [Future Leader 2017]

King, Ross D., Professor of Machine Intelligence, Computer Science, The University of Manchester, U.K.; Senior Visitor, Artificial Intelligence Research Center, Japanese National Institute of Advanced Industrial Science and Technology, Japan

Liepert, Bernd, Chief Innovation Officer, KUKA AG, Germany

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

Oskamp, Anja, Rector Magnificus, Open University of the Netherlands, Netherlands

Sandvik, Pia, CEO, Research Institutes of Sweden (RISE), Sweden

Opening Remarks

Chair: Sankai, Yoshiyuki

The Chair opened the session by giving a brief introduction of each speaker.

The session speakers were then invited to offer comments. Discussions began with science for AI systems. It was noted that faster computers, greater amounts of data, as well as better machine learning methods are driving the application of A.I. and robotics to science. Such systems have multiple advantages: the ability to remember vast numbers of facts, near perfect reasoning and logical skills, the capability of working 24/7, etc. It is expected that the application of A.I. and robotics to science will help deal with the challenges facing mankind such as food security, and better healthcare.

The subject of megatrends such as aging societies and workforces was brought up, and the importance of creating robots to meet this challenge. Regulatory hurdles which will necessitate cooperation with policy makers and other stakeholders was raised as a challenge, as were specific areas where robotics can assist, including healthcare, maintenance and inspection automation, intelligent farming, and other forms of smart automation allowing SMEs to participate in the industry. The societal questions of how the introduction of robots into society may affect humans was also discussed. It was also noted that we must teach and train current and future generations to interact with robots in a safe and responsible way.

Another subject raised was around the technological evolution of robots. It was pointed out that for robotics to be safely installed in society, the peripheral environmental and support infrastructure is also indispensable. A comment was made that remote diagnostics would be important going forward to ensure a stable environment. It was added that we should expect standards in the field that allow robots to work smoothly. Another comment was added that beyond technical improvements, the evolution of robots requires a proper legal and social environment where robots are accepted.

Next, the speakers discussed legal expert systems and decision-making. It was pointed out that in general, people were not in favor of having non-humans make decisions on human matters. Another commentator added that such discussions about future intelligent systems and A.I. were currently underway in Europe, and that there were many remaining questions which had a societal impact on a macro and micro level.

The resource cost of robotics was also raised and the fact that robotic technology is an expensive technology. Another point made was that individuals with lower social economic status or skills may believe that robots will not benefit them. A question was then raised regarding how robotics can create a sustainable business model so poorer peoples and societies can benefit from these technology developments as well as understand how they may benefit from robotics.

The speakers also addressed cross disciplinary collaboration in robotics and the use of A.I. in industry and policymaking to advance sustainable development goals. A point was made that with the help of A.I., massive amounts of data could be used to address poverty and climate change, agriculture, healthcare, waste management, automotive driving, and communication amongst other areas. It was added that in-depth dialogue between social

scientists, policymakers, and engineers was required to overcome technical and ethical questions.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon uncertainties around robotic technology, building ethical decisions into software, and media coverage of robotics and their effect on jobs markets.

There was also discussion of the modern definition of robotics, breakthrough applications for robots such as in the home or caring for the elderly, the proper allocation of roles between robots and humans with the aim of improving quality of life, new forms of automation in factories, and the aesthetic design of robots.

The participants then highlighted societal acceptance and the impact of robots, and the definition and lifecycle of robotics. The timing of introducing legislation in relation to robotics, and job loss in certain industries through the introduction of robotics was also discussed.

There was also discussion around making robotics cheaper and more accessible, changing negative mindsets around automation and robotics, and using A.I. and robotics for image classification. Lastly, labor force-sharing between robotics and human was discussed.

Environment
Climate Change

[Chair]

Murray, Cherry A., Benjamin Peirce Professor of Technology and Public Policy (on sabbatical leave), John A. Paulson School of Engineering and Applied Sciences, Harvard University; Visiting Professor of Physics (visiting on sabbatical), University of Arizona, U.S.A.

[Speakers]

Gholami, Mansour, Minister, Ministry of Science, Research and Technology, Iran

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

Luers, Amy, Executive Director, Future Earth, Canada

Takahashi, Yasuo, Vice-Minister for Global Environmental Affairs, Ministry of the Environment, Japan

Takeuchi, Kazuhiko, President, Institute for Global Environmental Strategies (IGES); Director and Project Professor, Integrated Research System of Sustainability Science (IR3S), The University of Tokyo, Japan

Zehnder, Alexander J.B., President and Founder, Triple Z Ltd., Switzerland; Member, Board of Trustees, Nanyang Technology University, Singapore

Chair: Murray, Cherry A.

Opening Remarks

The chair opened the session by stating one of the main problems on the Earth is climate change, and to attain the interconnected goals of sustainable development, we all need to greatly reduce greenhouse gas emissions. The chair continued to explain the status of the U.S. in the event of the U.S. pulling out of the Paris Agreement. However, people, networks, and local governments in the U.S. still take the problem seriously. In addition, many cities and states making up the majority of U.S. GDP are setting goals for emission reductions, which means the U.S. is still a part of the agreement in essence.

The session speakers were invited to make comments and the discussions started with the progress of government climate policies in Japan, the need to reduce greenhouse gas as well as adapt to climate change while also creating economic growth, and Japanese private companies and local government's efforts to reduce greenhouse gas emissions. In addition, the speakers mentioned that the climate change adaptation plan will be revised every five years by the government's National Adaptation Plan, and Japan is putting in a lot of effort to open dialogues and take actions towards the mitigation of climate change.

The issues surrounding climate change were further discussed by mentioning that climate change is getting worse with the increase in severe climate events, there is a regional challenge of accessing water and natural resources, industrialization has resulted in extreme loss and destruction, and climate change and global warming are serious threats due to industrial activities. Additionally, the group discussed key points for overcoming climate challenges include putting renewable energies into developing countries, raising public awareness, and supporting moving towards a low carbon economy.

Following that, the speakers discussed the need for more human organization, change in government policies, and substantial social innovation. The group continued to emphasize that global dynamic collaboration between governments and social activities are needed and necessary.

Continuing the discussion, the point that big data is very useful and helpful in determining how we can and should interact with the environment was discussed. In addition, the fact that many sectors are working together to achieve the Paris Agreement target was mentioned.

A common theme that was brought up by the speakers was the local communities and local governments; local communities know more about what needs to be done in their regions to adapt to climate change.

Another subject discussed by the speakers was resources. Japan has reconsidered the use of nuclear energy. However, changing energy resources is also changing social structures. Therefore, in order to create a sustainable society, we also need to consider the influence of society on reorganizing environmental plans.

Discussion

A group discussion was held after the opening remarks. The participants discussed the issues of severe disasters changing not only the condition of plants and animals but also ecosystems, the need to rebalance business and society, the desire for governments to consider the economy when making climate change decisions, how thinking about adaptation locally and international collaboration are crucial for climate change progress, the daunting challenge of adaptation as the key factor in climate change, data showing that we are facing very serious problems, and the lack of political actions like nuclear power, carbon emissions, and increasing taxes.

There was also a discussion that emphasized that there clearly is a dilemma between a desire for gathering data to show and analyze what climate change is doing regionally and globally, and the distinct need of acting now with regards to climate change before all the data is known. The speakers mentioned that in the absence of data, pragmatism needs to be balanced. They went on to describe the need for an increase in monitoring in order to reduce uncertainty at a regional level, the implementation of fundable projects on the local level, and doing projects at small enough scales that we can learn from them.

Finally, the speakers explained that they found themselves focusing on the politics around climate change, not only is the science for adaptation needed, but also the evaluation of

the adaptation and if adaptation makes improvements or not. The speakers continued the discussion by mentioning the fact that animals can and will be able to adapt and evolve, but not quickly. Also, humans will not be able to adapt quickly. The speakers summarized that communicating the work of the IPCC is vital for progress, local and global forces need to work together, the criticalness of the research to formulate adaptation strategies, the need to explore national adaptation programs, and the importance of community engagement.

Environment
Utilization of Space and Ocean

[Chair]
Taira, Asahiko, President, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan

[Speakers]
Comparini, Massimo Claudio, Chief Executive Officer, e-GEOS S.p.A., Italy
Green, James L., Chief Scientist, National Aeronautics and Space Administration (NASA), U.S.A.
Martin, Christopher L., Interim Vice President, Science Programs, Kavli Foundation, U.S.A.
Wakata, Koichi, Vice President and Astronaut, Japan Aerospace Exploration Agency (JAXA), Japan
Williams, David, Executive Director, Digital, National Facilities and Collections, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
Vinayachandran, P. N., Professor, Centre for Atmospheric & Oceanic Sciences (CAOS), Indian Institute of Science (IISc), India

Opening Remarks

The chair opened the session noting that from the first time we captured an image of the Earth from space we had an understanding of the Earth as a single system, but with acceleration of human activities we are completely changing the planet.

Chair: Taira, Asahiko

The session speakers were then invited to offer comments. Discussions began with reflections on the activities of astronauts on space missions, and the experiments carried out, as well as Japan's contributions to space research. At the same time, concerns over the evidence of human activities and environmental changes viewed from space were reiterated. It was noted that space technologies are invaluable to be able to visualize global sustainability issues to support life on Earth.

Another aspect considered was the large amount of data generated on the Earth's water cycle, which can be used to model the health of the ocean ecosystem. Measurements include ocean color, ocean currents, ocean winds, sea surface height, sea surface temperate, which in combination with atmospheric measurements help us understand the oceans' impact on weather, climate, and life on Earth. It was pointed out that oceans are absorbing CO_2 from the atmosphere, increasing ocean acidity.

Next, the speakers discussed how salinity can affect ocean temperatures, and the relation between surface temperature and the whole body temperature. It was also noted that global sharing of data is key to a global model for oceanography. Modelling can also be modified to provide more accurate local forecasts taking into account local conditions. There was also discussion of tracking and cleanup of plastics in the oceans.

The speakers then discussed how humans' use of the oceans has changed tremendously from medieval times to the present, and the challenges that this presents. It was noted that we need to evolve our observing capabilities to adapt to the vastness of the oceans, while also improving spatial resolution to improve the accuracy of the models in local areas. In addition, it was noted that we need to work on education and capacity building.

The speakers discussed the processing of space data and how this improves our understanding of the planet and its evolution. Advances in space sensors will continue to improve the range of information that can be measured to provide even greater and more accurate data tracking changes in the oceans. It was noted that coastal areas in particular can benefit from these improvements in high-resolution ocean data.

The speakers then pointed out that looking at the universe around us can provide insights into our own planet. It was noted that non-profits can play a vital role is funding early-stage high-risk research, which might otherwise not be able to attract funding. The continuing role of ground-based telescopes in the study of space was also noted. It was pointed out that, according to FundingtheOcean.org, there is at least 500 million USD per year of ocean research funded by non-profits.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon taking actions, what can be learned from using satellites, how data should be disseminated

to the public so they can better understand how the Earth is changing on the local scale, and how satellites can provide accountability by seeing where emissions, or other harmful forces, come from.

The participants discussed key points including the rise of big data and cloud services, how advances in IT improve our ability to model and understand what is going on in weather systems and in oceans, ocean data sharing and appropriate use, and opportunities for better data integration. Regarding pollution, the challenge lies in education and action. Not only advocating for new programs was highlighted as being important but also continued funding.

Next, the participants explained the importance of increasing citizen's awareness to enhance ocean science. A main goal is to develop and sustain ocean use by understanding the ocean system. Using global satellites for observation is a very useful method of collecting data of the ocean system. To realize global and local observations simultaneously, more participation is needed from various countries.

Finally, the participants discussed in detail ways to start standardizing how data is collected and presented, and how to monetize and access data sets. The two-way exchange of data between scientists and those that are in the target environment was emphasized. The participants of the discussion also recognized that there are data sources that have not been tapped into which should be tapped into.

Environment

Environment and Health

[Chair]

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

[Speakers]

Murray, Virginia, Head of Global Disaster Risk Reduction, Global Public Health, Public Health England, U.K.

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

Peitsch, Manuel, Chief Scientific Officer, Reduced-Risk Products, PHILIP MORRIS PRODUCTS S.A., Switzerland

Quirion, Rémi, Chief Scientist, Government of Quebec, Canada

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

Watanabe, Chiho, President, National Institute for Environmental Studies (NIES), Japan

Opening Remarks

Chair: Steen, Tomoko Y.

The chair opened the session by explaining the importance of communication among policy-makers, scientists, and the public. Members of the public need to understand what risks the environment poses to their health. The chair also encouraged participants to include detailed suggestions for environmental regulations and the management of society.

The session speakers were then invited to offer comments. Discussions began with genetically-modified organisms (GMO), the use of which is widely debated. Some people mistakenly believe that GMO are dangerous. However, GMO can solve food shortages in developing countries, and alleviate environmental impacts by saving the area of

cropland to produce food and by reducing the emission of GHGs. We need to clear up this misunderstanding not only among policymakers but also religious groups. In developing countries, people need food and better nutrition. GMO are an invaluable solution to this problem.

Next, the speakers discussed the issue of smoking. Smoking is the number two risk factor for death and the number one preventable cause of non-communicable diseases. The primary cause of the harmfulness of tobacco is its combustion not the nicotine. Alternative nicotine delivery systems may be a solution to reduce the incidence of tobacco-related diseases but they need to be rigorously scientifically assessed.

Another topic was research on the impact of climate change on the Arctic. To study this, the local communities must be involved in the program design. It is also important to include researchers from different fields, including natural and social scientists. Policymakers need to be involved from the beginning as well. The warming of the Arctic has implications for biodiversity, pollution and health, such as increasing the incidence of various chronic diseases.

Next, the speakers turned their attention to climate change and planetary boundaries. The relationship between planetary boundaries, such as climate change, and health is largely unknown. One of the difficulties of addressing planet-boundary-related issues is their ambiguity and the indirect way in which they affect us. A variety of scientific tools must be used to identify the problems and possible solutions. There also needs to be more discussion among the health communities and environmental communities.

The speakers also discussed disasters and the impact on health. Disasters are major hazards globally that have a significant impact on morbidity, illness and mental health. The recent adoption of the 2015 UN Landmark Agreements of the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals and the Paris Agreement on climate change make for a more complete resilience agenda requiring action to develop systems where the reduction of extreme events and other hazards could reduce impacts on lives, livelihoods and health. Additionally better scientific assessments are needed to determine the impacts more formally. For example, Japan has had a difficult year so far with a measles outbreak, an extreme heatwave, several typhoons and significant flooding. The engagement of health and the environment is very important as well as the commitment to the implementation of the UN 2015 agreements.

Next, the speakers considered the impact of using air conditioning. Air conditioning exacerbates global warming by increasing carbon dioxide emissions. On the other hand, there have been more frequent and hotter heatwaves worldwide and people need to use air conditioning to protect themselves. However, some are afraid to do so, because of the emissions this would produce. A study has shown, however, that, because of improvements in the eco-friendliness of air conditioners, the benefits of using air-conditioning far outweighs the costs.

Discussion

Following the opening remarks, a group discussion was held. The participants first touched on how health professionals and scientists are in the primary position to relay information to the public. These professionals need to be able to work with industry, business and government to then be able to translate the information effectively. Furthermore, health information management presents an issue as we cannot yet identify the baseline of mortality rates which are particularly important for understanding the impact from disasters and extreme events associated with climate change, as well as other environmental toxins. More robust technologies and assessment tools are needed to improve this.

Another topic was GMOs. If the approach to GMO is thought of logically, humankind has been changing biological systems for a considerable amount of time, along with the environment and other factors. However, people often respond to this issue from an irrational perspective. GMOs can result in the doubling of food production while reducing the size needed for farming. Countries which adopt GMOs will see an increase in economic output and a reduction in mortality rate. Health and environment are inextricably linked to food security. The modernization of food production is also a reason why the group recommended GMOs as a way to ensure food security. There are many myths and much misinformation surrounding GMOs. Correct awareness of this topic is needed. Engaging politicians will help. Scientists also need to present a united opinion. In some countries it is not possible to investigate GMOs due to restrictions in legislation.

The participants also discussed systemic health. Systemic health research does not yet have a lot of data or evidence. Additionally, many research projects are too narrowly-focused to provide the correct data to identify systemic health problems. Wearable tools might be a possible solution or cooperation with other sectors. The participants then noted that the planet will adapt to climate change but humankind may not. In addition, there are many limitations imposed on humankind, one of these being time.

The chair concluded the session by saying that as someone teaching on the topic of environment and health, she is aware of many issues of environmental health, but she has to especially ask STS *forum* to agree to actively engage science and technology to support the UN landmark agreements: the SDGs and the Paris Agreement on climate change.

Cooperation in S&T

Science and Technology in Developing Countries

[Chair]

Yamanaka, Akiko, Special Adviser to the President, Economic Research Institute for ASEAN and East Asia (ERIA); President, International Tsunami Disaster Prevention Society, Japan

[Speakers]

Catlow, Richard, Foreign Secretary and Vice-President, The Royal Society, U.K.

Rao, V. Ramgopal, Director, Indian Institute of Technology Delhi (IIT-D), India

Rubinstein, Ellis, President and Chief Executive Officer, The New York Academy of Sciences (NYAS), U.S.A.

Subiyanto, Bambang, Vice Chairman, The Indonesian Institute of Sciences (LIPI), Indonesia

Subrina, Samia, Professor, Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology (BUET), Bangladesh [Future Leader 2017]

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

Opening Remarks

Chair: Yamanaka, Akiko

The chair opened the session by explaining the topics for discussion. These include the primary needs of developed countries, such as optimizing the use of limited resources in alignment with local needs, and basic needs such as access to quality healthcare, education and food security. Another topic is brain-drain. In addition, greater involvement of women in science and technology should be promoted in order to ensure sustainable development. The chair also explained that the digital revolution has made greater access to knowledge and technology possible, accelerating opportunities to increase economic development. Furthermore, government-industry-academia collaboration is needed when making strategic choices with benefits and risks. In order to

pursue science and technology in developing countries, social science perspectives such as social resilience, common interests and an age of balance should be introduced as well.

The session speakers were then invited to offer comments. First, they spoke about the needs of the developing world, namely strong, self-sustaining science, the economy, health, prosperity and culture. For example, in Africa, higher education and the fostering of future leaders are important. Funding from domestic and international sources is also required.

The difference in the problems faced by developed and developing countries was then raised. Developing countries need to ensure their issues, goals and resources are aligned. Educating young people in science and technology is one useful approach. However, brain-drain has emerged as an issue. Additionally, not all people have equal access to education. Girls are often disadvantaged.

The speakers then talked about jobs, education and research in developing countries. Governments need to think about the best ways to educate people. They must also create enough jobs at a time when AI is replacing some human jobs. Additionally, many institutions are doing good scientific research but not necessarily research that solves local issues. Research should be more focused on local needs. Greater collaboration between academia and industry should help. The specific example of India was discussed, where the leading academic institutions in the country have been asked to adopt 5 villages each and work towards their development through innovative technological solutions and prototype development.

Next, the speakers discussed educational challenges. Many children in developing countries have no chance to be educated. More new teachers are needed. Moreover, teachers should be educated in a way that matches children's needs. Funding must also be provided in the right places.

The speakers also talked about the experience of Indonesia. Indonesia is promoting continued economic growth to improve community welfare, maintaining the sustainability of people's lives, maintaining equality and inclusiveness, and promoting good governance to maintain quality of life. It is leveraging natural science and social science to achieve these goals.

Another topic was the importance of economic competitiveness. Competitiveness increases productivity and enhances the quality of people's lives. Every country that has developed has focused on talent, technology, investment and infrastructure. With the digital revolution,

countries no longer need huge infrastructure. Many developing countries recognize the need for science and technology investment but one area that may be lacking is having long-term investment strategies in areas such as education.

Discussion

The participants then took part in a group discussion. They first spoke about the importance of knowing and educating local people. Specific local needs needed to be addressed, and local and national governments need to work together. Encouraging people to come back to their own country after learning outside is important too. Better frameworks for exchange programs are also needed.

The participants then discussed the importance of social science. Business assistance is also required as well. Furthermore, technologies should be used to assist humans instead of replacing them.

Another point raised was that adequate budgets should be allocated for science and technology. The participants also pointed out that the policymaking process in developing countries is not clear, and that is a big problem. Solutions must have a local context and good

understanding of the local context is important. Qualified teaching staff are important as well. Collaboration at the local, regional and international levels might help solve this and should be encouraged.

Another significant issue is gender disparity, such as education of girls. Digital education is also important and education will foster more capable and specialized human resources. Furthermore, education should be connected to local business and infrastructure.

Funding is another important issue. Collaboration with local communities and ensuring technology that is deeply connected to local needs are important. Finally, the participants pointed out that a more precise definition of "developing countries" is needed.

Cooperation in S&T

Collaboration among Academia, Industries and Government

[Chair]

Sirilertworakul, Narong, President, National Science and Technology Development Agency (NSTDA), Thailand

[Speakers]

Gardingen, Paul van, Deputy Pro Vice-Chancellor, Global Engagement, The University of Leicester, U.K.

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

Matsumoto, Hiroshi, President, RIKEN, Japan

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

Ohno, Hideo, President, Tohoku University, Japan

Tan, Chorh Chuan, Chief Health Scientist, Ministry of Health (MOH); Executive Director, MOH Office for Healthcare Transformation, Singapore

Tian, Gang, Vice President, Peking University, China

Opening Remarks

Chair: Sirilertworakul, Narong

The chair opened the session by raising the question of how to create the economies and nations of the future through collaboration among academy, industry and government. Such collaboration can also tackle international poverty. There have been successful cases of collaboration and also many failures that we can learn from. There are many issues that need to be considered including open innovation, policies related to academic career paths, and the involvement of the private sector in research.

The speakers then discussed collaboration among higher education institutions, industry

and governments. In emerging economies, these groups must work together to prepare young people for the job market. Further consideration is needed, such as how to train students and design research. Interaction at the local and global levels can also help promote collaboration. Furthermore, innovation is also needed, but sometimes institutions cannot innovate, despite the will to do so, due to lack of funding.

The role of academia in innovation was then raised. Academics are the creators of ideas, but research is expensive. Governments should help academia pursue worthwhile research, but they are too often preoccupied with their existing interests. Industry can often be too focused on commercialization. Good collaboration is needed among these three groups to produce better innovation.

Another subject was RIKEN's experience pursuing such collaboration. RIKEN is collaborating with government and industry to change society. Examples include research and studies for the creation of real products. Scientists usually prefer to do research on their own and based on their own interests, but they must share their research with others to create innovation.

The speakers also talked about the ecosystem for government-industry-academia collaboration. Universities generate the seeds for innovation. To ensure that innovation is sustainable, industries can provide financial help, while governments can implement the right policies. Academic institutions should be able to help connect researchers with governments and businesses, for example by establishing industrial advisory boards.

Next, the speakers discussed the governments' role in such collaboration. Tohoku University has succeeded in collaborating with industry using a new model called "BUB" or "business to university to business." The university is expanding collaborative research with businesses, for example in AI and IoT research. Through such joint research, it has secured funding for other research.

The speakers also addressed ways to promote and accelerate innovation. Innovation is about having the right talent who can take good ideas, make them better, and turn them into the reality. Government, industry and academia are all competing for the best talent and there needs to be more talent circulation among them. Support from the general public for cutting-edge research areas can also promote innovation.

The discussion then focused on government support for research. In China, the government is mainly interested in leveraging science and technology for economic growth, so universities are mainly focused on technological innovation. However, they should also conduct more fundamental research as well as industry-related studies. Financial support from the government and from industries is also important.

Discussion

Following the opening remarks, a group discussion was held. The participants first discussed the mismatch in the needs of academia, government and industry. Setting shared goals, and sharing visions and scenarios can help promote collaboration among them. At the same time, compromise is also necessary. There can also be cultural differences among these sectors, which can be resolved through more communication.

In addition, a policy of openness is helpful. With regard to joint university-industry research, the government can play a facilitating role. The sharing of facilities and training systems is a useful practical means of promoting such collaborative research. Meanwhile, companies can also get involved with and enhance education. Long-term investment in education by the government is very valuable as well.

The participants also touched upon intellectual property issues. These can be major issues and a barrier to collaboration. The questions of who is paying for a piece of research and who owns it, must be carefully considered. Small companies also often lack intellectual property of their own and need support from the government and academia.

The value of diversity was also raised. Every sector and organization has different interests. Being aware of this diversity of needs and interests is important.

Lastly, the participants discussed the speed with which science and technology is advancing and the need for all parties to be willing to change and able to act quickly.

Cooperation in S&T

Science and Technology Diplomacy and International Collaboration

[Chair]

Hamaguchi, Michinari, President, Japan Science and Technology Agency (JST), Japan

[Speakers]

Douraghy, Ali, Senior Program Officer, National Academies of Sciences, Engineering, and Medicine; Senior Advisor, Earth & Environmental Sciences Area, Lawrence Berkeley National Laboratory, U.S.A. [Future Leader 2017]

El Hassan, Sumaya bint, President, Royal Scientific Society of Jordan (RSS), Jordan

Gibbs, Doon, Director, Brookhaven National Laboratory, U.S.A.

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

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

Zerbo, Lassina, Executive Secretary, Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO), Austria

Opening Remarks

Chair: Hamaguchi, Michinari

The chair opened the session by confirming the points to be discussed. The nature of science, technology, and innovation has promoted international collaboration, as they are difficult to do by single nations. Why we need diplomacy is clear; each country has different interests, and international institutions are usually following certain countries' interests. Thinking of how to collaborate and how to educate human resources with science and technology diplomacy is important.

The session speakers were then invited to offer comments. The speakers mentioned that science diplomacy has implemented a lot of impressive projects, relies on funding, and relies on government and multilateral

support. The absence of strong scientific leadership is a problem now, and science diplomacy must take the role of changing it.

The speakers described two types of initiatives focused on early-career leaders that should be considered seriously by countries invested in advancing their science diplomacy efforts. The Global Young Academy (GYA) and the nearly 40 country-level National Young Academies (NYAs) represent a rapidly-expanding global network focused on shaping the future through engagement in science policy, communication, and outreach, including at high-level international forums. Another type of program, science and technology policy fellowships, is a mechanism that connects the analytical skills of early-career science leaders with policy-making needs in technical and foreign ministries as well as parliamentary bodies.

Another subject the speakers discussed was science and technology issues associated with international collaboration. International collaboration with science and diplomacy is increasing. One benefit is enhancement of science and technology, and that moves enterprises forward. In addition, competition and diversity of talent have increased by international collaboration.

Next, the speakers discussed science for diplomacy and diplomacy for science. The Comprehensive Nuclear-Test-Ban Treaty was introduced as one of the greatest examples of the nexus between science and diplomacy as its mission stems from understanding how science can drive policy, in order to reach the goal of putting an end to nuclear testing. Science can demonstrate technical solutions to shared problems and help policymakers solve them. Science and skilled scientists are important factors in finding solutions and solving problems. In addition, understanding political differences is an essential element in overcoming obstacles now and in the future.

The speakers also addressed Japanese experiences in science and technology diplomacy collaboration. Scientists played a key role in advising Japanese foreign ministers in terms of science for diplomacy. As an example of the international collaboration of Japan, the joint research program known as SATREPS and human resources cooperation for the youth and higher-education levels implemented by JST and JICA were introduced as well.

Lastly, the speakers discussed the fact that scientists have an advantage in the global community because they speak the same language to communicate with each other while people in other sectors are divided by language, culture, and politics. Additionally, governments should

allow more possibilities for scientists since they are the people willing to make progress in society. A challenge this poses is finding the ways to have dialogue with politicians.

Discussion

The participants then held a group discussion. It is very useful that scientists have a common language for discussions. Scientists should also be good communicators. Scientists have the imagination needed to achieve breakthroughs. The difficulty is in communicating their ideas to policymakers and politicians. Academic organizations need help from governments and companies.

It was also noted that models are not 100% accurate. Scientists need to make decisions to determine what is accurate. Politicians can communicate with the public, so it is important to educate politicians scientifically. In addition, the participants pointed out that the aim of science diplomacy is to bring people together. Scientists should be provided with training in negotiation and diplomacy. Another point is that scientists have different perspectives on the same topics so policymakers need to hear these different ideas from scientists too.

The participants then turned to the issue of brain-drain. Providing visiting programs is still important but this issue must be addressed. Such global issues should be addressed by science and global enterprises together.

Lastly, the participants emphasized that communication at all levels is required. Collaboration can be activated at the individual level too. Communication should also occur across fields. If these can all be achieved, science diplomacy will gain more trust in the future.

S&T and Society
Innovation Ecosystem

[Chair]
Maex, Karen, Rector Magnificus, Board, University of Amsterdam, Netherlands

[Speakers]
Ataka, Kazuto, Professor, Faculty of Environment and Information Studies, Keio University; Chief Strategy Officer, Yahoo Japan Corporation, Japan
Chen, Dongmin, Professor, School of Innovation and Entrepreneurship, Peking University, China
Gross, David J., Chancellor's Chair Professor of Theoretical Physics, Kavli Institute for Theoretical Physics, University of California, Santa Barbara, U.S.A. [Nobel Laureate 2004 (Physics)]
Maesincee, Suvit, Minister, Ministry of Science and Technology (MOST), Thailand
Meyerson, Bernard S., Chief Innovation Officer, IBM Corporation, U.S.A.
Noyori, Ryoji, Director-General, Center for Research and Development Strategy, Japan Science and Technology Agency (JST), Japan [Nobel Laureate 2001 (Chemistry)]

Opening Remarks

Chair: Maex, Karen

The chair opened the session by addressing the point that whilst creating an innovation ecosystem has long been a topic of STS *forum*, the impact of innovation is changing in a considerable number of areas, and thus it is still a subject of upmost importance. There is also a need to rethink the role of innovation in various areas of society and how the goals of society can be defined. Furthermore we must consider who speaks on behalf of the public.

The group remarked about how restrictions such as high prices of existing technologies can force people to create innovation ecosystems. Having a diversity of inputs helps drive innovation. Creating ecosystems where we can learn and cooperate will be beneficial. It remains to be seen but AI may develop to the point of being able to identify areas necessary for creating an innovation ecosystem.

The discussions began with a focus on the perspective of continuous changes. All fields are facing massive innovation, so we should enhance the speed of innovation. Some areas have been seriously lacking in innovation in Japanese society. Bottlenecks and excessive regulation in the government and academia must be removed to encourage innovation. Resources should be reserved for the future.

Another subject was creating innovation in theoretical physics, which involves open and transparent systems and opportunities for young people and new ideas. Surprisingly, a missing link between the two spheres of physical sciences and social sciences needs to be bridged, because the social sciences are similar in experimental ability and growth rate.

The speakers discussed entrepreneurship ecosystem development. The younger generation has enjoyed early financial success especially in "unicorn" companies. This progress has happened in both China and the US. In addition, our social challenges require close attention so higher education must be a strong advocate for social innovation.

The group mentioned disruption of the 21st century and our new cultures of living, working and learning. They questioned how to reinvent society and change it from an individualistic society (Me-Society) into a collectivist society (We-Society). Open collaborative platforms and sharing society will result in inclusive innovation and, hence, inclusive growth for everyone in the society.

The following subject addressed was data-driven approaches to scientific development. The scientific community may fossilize unless they promote "anti-disciplinary" research. Economic factors are not the only reasons for innovation. We should consider the eventual outcomes of our current approach. Nature and humanity are the ultimate goals.

Discussion

Following the opening remarks, a group discussion was held. The groups tried to draw parallels between a living ecosystem and an innovation ecosystem. Sustainable and self-governing qualities could be some of the goals involved. The ecosystems need to be balanced to avoid problems. Political influence, education and skills are also going to be vital.

The group questioned the government's role in creating an innovation ecosystem. Afterwards the participants addressed cooperation and unity for creating an ecosystem. Reducing the regulatory system would also encourage innovation. Governments should be open-minded and not restrictive to garner better innovation. Startups need cooperation from academia, finance, and a more flexible education system.

The members of the group pointed out that not only government policies but also bottom-up solutions are important. Individualism is one quality of an ecosystem. Homogenous societies actually hinder progress. A sandbox environment would be a good place to experiment. Mindset is the most important barrier when creating an innovation ecosystem.

The participants remarked that uncertainty and speed are qualities needed for an entrepreneur. Not only is it important to create an ecosystem but also to keep it growing. Smaller geographical areas might be better placed to support ecosystems. Mindset is also important and government policies should promote innovation and not be restrictive. The discussion also highlighted that ecosystems for research are about brilliant teachers and environments which will allow for creativity. In business, the ecosystem should reflect what would provide success.

The group also agreed on the importance of social benefit but identifying this benefit for society is difficult. Large government funding projects may not lead to the best innovation ecosystem. Businesses and also universities need to develop the innovation culture. The topic of the

government's changing role was mentioned, and this needs to realign around non-traditional policies. Social innovation and non-technological innovation also need to be considered. The global-to-regional idea was also discussed. Cutting edge science and technology trends have a broad scope and are simplified and monopolized. Mindset and culture are also important but changing them is a longer process.

The participants noted that there are many factors that make up innovation. The entrepreneurship aspect probably cannot be changed. Education can also affect the culture of innovation. The paradigm of winners and losers should be changed. The role of capacity building and sustainable approaches were also discussed. Cities and regions may be more experimental and therefore better places to start building an ecosystem.

S&T and Society

Policy Making in Science and Technology based Society

[Chair]

Kleiner, Matthias, President, Leibniz Association, Germany

[Speakers]

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

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

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

Mu, Rongping, Director-General, Center for Innovation and Development, Chinese Academy of Sciences (CAS), China

Prendergast, Patrick, Provost & President, Trinity College Dublin, Ireland

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

Opening Remarks

Chair: Kleiner, Matthias

The chair opened the session by exposing science and technology's role and application for society. Science operates – without a doubt in and for society – but it is often just driven by mere curiosity. However, can this unique role continue in the face of continuing global challenges, increasing complexity and the need of a literately mediating interface between science and society? The chair posed four questions to the group: How can science best contribute to informed political decision making? Is mission-oriented research funding the best mode to deal with grand challenges? Do national governments need to synchronize their innovation strategies internationally? How do we advocate the role of science to the public?

The discussions began by answering the chairs questions. Science should be aimed towards policy and vice versa. Mission-oriented research is one way to do this, and it is particularly effective for developing countries. Moreover, national governments have to synchronize, but synchronization at the regional level is also needed. Science interacts effectively through the media and the legislature to reach the public.

Following, the discussion highlighted that the way of thinking of politicians is different from academia. Politicians consider public opinions when making decisions, whereas academia does not. Contrastingly, academia requires financial support and this is often only given if they present evidence to politicians. Academia in Japan is failing the public through lack of education about evidence, and they have failed graduates who study abroad often to gain skills and knowledge, thus university reform is needed.

Another topic was that capital, finance, and politics are vital areas that the scientific community needs to cooperate with. These areas are aligned to the public in a way that science is not. A government initiative in the UK attempts to solve this problem. It attaches scientific advisors to central government. This has transformed the input to UK policy for the better. If science does not adopt the models used by these public facing areas, it will not drive the decision chain.

The group discussed the differences in value creation from the technological, scientific, economic, and social viewpoints. While science and technology drives innovation and creation, it does not provide a clear value for the public. The constant development of science and technology means that it becomes more complicated. Evidence-based policy-making needs more support from the scientific community to prove its value to the public.

The speakers mentioned how science can best contribute to informed-decision making and universities' chief role in the education of decision-makers. The people who eventually create society are not scientists and politicians, but lawyers and teachers. Universities should aim to educate these most influential people. They should provide them with individual benefits such as financial gain, and public benefits through volunteering and entrepreneurship. In this way, universities can keep a strong connection to society and encourage their graduates to act responsibly.

The following area of discussion that was raised was the link between science and society through scientific advisors and orientation of research. The science advisors bridge the gap between the scientific community and the world at large. The wisdom of science must be maximized to create benefits for the society through the knowledge structuring process. That helps up keep an appropriate balance between mission-oriented research work and curiosity-driven work, as they both contribute to solve society's problems.

Discussion

A subsequent group discussion was held. The role of universities and research institutions (outside universities) in society and how they connect to society was discussed. Universities and research institutions should encourage the mobility of researchers to advance their own careers. As well as this, universities have an opportunity to tackle the issues of communication with policy-makers at the source as politicians are often educated at universities. Another area universities could be effective is if they create institutions to guide advisors and policy-makers.

The group also discussed the different approaches to funding science and technology research. Currently, there is mission-oriented research and curiosity-based research. There was a strong consensus that both of these are required and need to be synergized. However, policy-makers and researchers also need a clear understanding of the needs of society before they create these missions. Once these missions are created, they must be national, regional and international.

It is crucial for scientists and politicians to understand each other. To do this, universities must communicate with policy-makers. Scientists themselves must become science communicators and translate their language so lay people could understand. Also, they should inspire young people as they may be more persuasive, and use intermediaries to communicate to the public who can effectively translate for them. Likewise, if approached from the other perspective, policy-makers could be trained to understand that evidence is not always definitive and clear. In addition, the culture of the experts, and trust in them, has been eroded because of this distance between academia and the public. The issue of communication from academia is not only relevant externally but also prevalent within it. The group raised the issue of scientists who do not agree on policies amongst themselves, because of this, there needs to be more engagement among scientists. An additional issue affecting communication is that good policies fade away due to the news cycle of new media.

S&T and Society

Science and Technology Literacy in Digitalized Society

[Chair]

Fuchs, Alain, President, Université PSL (Paris Sciences & Lettres), France

[Speakers]

Arima, Akito, Chancellor, Musashi Academy of the Nezu Foundation; former Minister of Education, Science, Sports and Culture; former President of the University of Tokyo, Japan

Chi, Youngsuk, Chairman, Elsevier, U.S.A.

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

Witherell, Michael, Laboratory Director, Lawrence Berkeley National Laboratory, U.S.A.

Yogeshwar, Ranga, Science Writer, Germany

Opening Remarks

The chair opened the session noting that although modern society depends increasingly on scientific and technological advancement, it is not necessarily scientifically or technologically literate, and role of universities must be considered in facing the scientific and social challenges this raises.

Chair: Fuchs, Alain

The session speakers were then invited to offer comments. The discussions started by considering how to strengthen scientific education in light of the fact that many people have a fear of complicated scientific concepts, particularly in Japan. While Japanese students rank higher than their international peers in science, the scientific literacy of the Japanese populous is considerably lower. It was noted that while Japan was once a leader of science and technology, it has fallen behind over the past 10 years, and this needs to be addressed throughout primary, higher and lifelong education.

The speakers then highlighted that Japanese universities focus on teaching information rather than problem-solving methods and skills. These problem-solving skills are important as they can be combined with computer and data science to create meta-skills that are useful far beyond a specific discipline. Additionally, computational thinking should receive emphasis as it helps with problem solving. Thus, we should all readdress what kind of areas are fundamental; literacy or skills.

Beyond this, the speakers considered the impact of science and technology's advancement which is outpacing laws, educational systems, and corporate guidelines. One area of advancement, AI, has divided expert opinion with its astonishing progress. However, as we do not fully understand the conclusions of a world impacted by AI, we have not changed our institutions and systems. We need to be equipped to use these technologies safely and responsibly. In addition, we need to bridge the gap between science and technology research and the rest of society, and also leverage the power of AI to understand our research faster.

Subsequently, the participants debated the dramatic changes in the workplace due to technology. The solution must be better than simply extending the length of education. Challenging research should be a central part of education and student should take on projects in which the answer is will not come from a book. A research intensive environment could help. Now, society needs more opportunity to grow. There has been a regressive trend where students from disadvantaged backgrounds are no longer choosing research positions, and may need longer to qualify with science degrees.

Afterwards the group centered on the outside world of the media and television. In this non-scientific world alternative facts are spreading widely and there has been a growing discrepancy between perception and facts. This is problematic because perceptions change policy. Classical media has been replaced by social media, and due to this change, science is losing the battle of facts and perceptions. We need to more clearly communicate science to the wider society because most people cannot read statistical data or understand risk and uncertainty. This can serve to strengthen the roots of a civilized society.

Discussion

A subsequent group discussion was held concerning the topics taught at universities and schools. In undergraduate education, the topics should be science-oriented. In addition, learning institutes should focus on problem-based learning and teaching students to

be curious and not memorize facts. The group posed the questions about the possible methods, whether it is scalable and if any examples already exist.

Furthermore, nowadays, university diplomas seem to take precedence as the student's goals instead of gaining knowledge. The group questioned if universities should change testing methods from exams to projects. There is also a need to provide incentive for lifelong learning, where older people can learn and in turn, teach others from their experience. STEM fields may, in fact, encompass skills that these lifelong learners require. Moreover, funding for education programs could be offered via companies or governments to help bridge the gap in the literacy of science and technology. There was some agreement among the group that learning, at some stages should not be too specialized and a return to studying the classics may be beneficial. Others in the group warned against centering their approaches on gifted students, and suggested that we must consider the middle-ground of ability. During the discussion around lifelong learning, it was emphasized that we must not lose focus of the fact that learning should be enjoyable for the entirety of one's life.

Another area that the group focused on was the method of communicating. Because science and technology is a complicated field, it may require a common language to be able to communicate it to people from outside the field. There were those who had concerns about oversimplification of complicated scientific concepts and perhaps another body could communicate on behalf of the scientific community. In addition, the participants highlighted the fact that communication should be two-sided. In some respect, these communication efforts should be focused on inspiring the younger population.

ICT
Artificial Intelligence (AI) and Society

[Chair]

Srikanthan, Thambipillai, Executive Director, Cyber Security Research Centre, School of Computer Science and Engineering, Nanyang Technological University, Singapore

[Speakers]

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

Kaili, Eva, Chair, Science and Technology Options Assessment (STOA), European Parliament, Belgium

Lao, Shihong, CEO, SenseTime Japan Ltd., Japan; Vice President and General Manager of Automobile Business Division, SenseTime Group Limited, Hong Kong

Screven, Edward, Chief Corporate Architect, Oracle Corporation, U.S.A.

Tanaka, Tatsuya, Representative Director and President, FUJITSU LIMITED, Japan

Yamamoto, Yoshihisa, Program Manager, ImPACT Program of Council for Science, Technology and Innovation, Cabinet Office (CAO), Japan Science and Technology Agency (JST), Japan; Professor (Emeritus), Applied Physics and Electrical Engineering, Stanford University, U.S.A.

Opening Remarks

Chair: Srikanthan, Thambipillai

The chair opened the session by explaining the session would consider the factors that fuel the massive deployment of AI solutions, future directions, as well as the societal implications, opportunities and challenges, from the perspectives of industry, academia, and policymakers.

The session speakers were then invited to offer comments. Discussions began with how the advances made in recent years in deep learning based facial recognition technology has rapidly surpassed the traditional facial recognition technologies. It was pointed out that the environment in China benefits AI research thanks to the greater availability of big data required

for training machine learning models, broad investment funding and government support for startups, and a strong entrepreneurial spirit. It was noted that autonomous driving technology made possible by AI can reduce traffic accidents, particularly among elderly drivers.

The discussion then shifted to the issue of applying machine learning to business and organizational problems, rather than the more common current applications in recognition. It was noted that AI requires scientific techniques, huge amounts of data, and very careful management of data, particularly with regard to security. The need was highlighted for AI in tasks such as detecting and responding to cyber threats, where human involvement would be too slow, as well as in creating chatbots to improve the experience of workers in finding information.

The speakers noted that there are initiatives underway to encourage open collaboration among various enterprises or ecosystems worldwide. It was noted that there have been challenges to apply AI to society due to the black box problem meaning that it cannot be trusted with mission-critical applications. One solution to this problem is the development of technologies to explain how AI arrives at its results making it more trustworthy, which should allow it to contribute to mission-critical areas such as medicine.

Next, the speakers discussed the topic of combinatorial and continuous optimization problems, such as lead optimization in drug discovery, resource optimization in wireless communications, and routing in power and transport networks, for which computational time scales exponentially with the problem size in modern computing systems. It was noted that quantum computing could revolutionize performance in tackling these problems. Research in Japan to operate a quantum neural network architecture at room temperature could make this a reality. It was noted that studies in the US are looking at the role of quantum information processing in the human brain, to improve our understanding of high-level brain functions such as cognition, consciousness and decision-making, and even mental disease.

The speakers also tackled the issue of AI in social newsfeeds, and how this can impact our decisions. It was noted that governments need to understand the impacts and to provide a safety net for the protection of citizens. The GDPR regulations were raised as an example of an attempt to improve governance of data to provide better security and privacy protections, and to clarify that responsibility lies with individuals not machines. It was pointed out that since we can be manipulated we need to make sure that our children understand the potential for manipulation, in order to protect themselves.

The speakers then discussed how great diversity and tight constraints can drive revolutionary approaches through necessity. One example presented was the use of thermal imaging and machine learning analysis for breast cancer screening, at one-tenth of the cost of traditional screening. In addition, it was noted that while the brain uses 20W of energy the equivalent AI would consume several orders of magnitude more energy. The challenges faced by startups due to a multitude of different regulations globally and in getting access to big data were also raised as an issue.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon scenarios for AI use, such as in disaster prevention, reducing costs of medication, and for factory automation that could remove the need to undertake dangerous tasks. Participants highlighted the importance of ethical use of AI, as it is already widely used but can make mistakes, and it was noted that transparency is somewhat contradictory to AI. It was therefore suggested that the limitations of AI should be clearly explained to users. There was also discussion around the tensions between use of data and sharing of data, protocols for data use, obfuscation of personal data, ownership of data, accountability, data transparency, and social acceptance. It was suggested that discussion between social sciences and hard sciences is required to address these issues. Use of neuromorphic networks or quantum computing were suggested as potential solutions to address the huge energy costs of AI. Meanwhile, it was noted that society needs to address the skills shortage in this area, including teaching staff. Finally, the participants noted that further efforts are needed to address concerns over data management and the fallibility of AI.

ICT
Cybersecurity

[Chair]
Tomita, Tatsuo, Chairman, Information-technology Promotion Agency, Japan (IPA), Japan

[Speakers]
Romine, Charles H., Director, Information Technology Laboratory, National Institute of Standards and Technology (NIST), U.S.A.
Taniwaki, Yasuhiko, Director General, Telecommunications Bureau, Ministry of Internal Affairs and Communications (MIC), Japan
Thompson, Herbert Hugh, Chief Technology Officer, Symantec Corporation, U.S.A.
Yokohama, Shinichi, Chief Information Security Officer (CISO), NIPPON TELEGRAPH AND TELEPHONE CORPORATION, Japan
Zehavi, Roni, CEO, CyberSpark, Israel

Opening Remarks

The chair opened the session by explaining the session would address the key issue for boardrooms of cybersecurity, noting that in the coming era of Society 5.0, enterprises will be processing huge amounts of data, with unprecedented levels of interconnectivity, and meeting the challenges of privacy protection, data security and stable business operation will be a great challenge.

Chair: Tomita, Tatsuo

The session speakers were then invited to offer comments. Discussions began with an explanation of the development of measures and regulations for cybersecurity in Japan in recent years, as well as Japan's cybersecurity strategy. In addition to country level measures, the need to develop international rules in cyberspace was highlighted. Global coordination and information sharing is also important for the development of IoT devices where lifecycle management and security by design is important, and it was suggested that there need to be incentives for enterprises to share information on cyber threats. It was also noted that cybersecurity insurance needs to become more commonly available.

Another subject raised was the human factor of cybersecurity. There is a growing gap between accurate perception of utility versus the accurate perception of risk, as users are ill-equipped to make sound decisions when interacting with and making decisions about the technologies that they use and come into contact with in their daily lives.

Next, the speakers discussed the problem of trust. It was noted that when purchasing items, we put our trust in the producers, manufacturers, designers and developers; and when visiting a doctor or hospital we put our trust in medical professionals. But in the ICT era there are additional players that are not committed to this unwritten agreement of trust, that can gain access to the systems that we use and subvert them, which can cause us to lose the trust that is the backbone of our society.

The speakers also highlighted the fact that cybersecurity is a business issue rather than a technology issue. Common misunderstandings were shared, such as the belief that cybersecurity is about Internet usage, whereas in fact it is about digitization of business, going far beyond Internet usage, and that cybersecurity protection should and will be provided by the government, where in reality businesses must take care of themselves. An additional point shared was that management must accept that zero risk is impossible, and companies must take a risk-based approached to managing risk.

The speakers elaborated further on the subject of cultivating trust, noting that cybersecurity risk for a company should be akin to reputational risk and financial risk management. With AI there are complex security challenges as there are several potential vectors for subversion of AI models. IoT also presents huge risks. In addition, the arrival of quantum computing also poses challenges, as although theory suggests that secure communication should become possible, existing PKI based encryption will become redundant, and therefore quantum resistant cryptographic algorithms need to be developed.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon the principles for protection of data when sharing information on cybersecurity, prevalence

of malware on IoT devices, certification for security of IoT devices, and the difficulties of providing cybersecurity insurance due to the difficulties of estimating risk. One area of discussion considered the approach to setting up cybersecurity infrastructure that should be taken for a country becoming high-tech without any background in cyber was discussed, such as setting up a security operations center (SOC). More broadly, it was pointed out that we need better communication on cybersecurity issues to create a cybersecurity-informed populous. The participants noted that there are too many important issues, challenges and concerns in cybersecurity, but highlighted that one of the key areas is education, particularly for top management. Finally, it was noted that a cross-border ecosystem must be built to nurture the next generation of cybersecurity talents.

ICT
Utilization of Big Data

[Chair]

Petit, Antoine, Chairman and CEO, National Center for Scientific Research (CNRS), France

[Speakers]

Desai, Uday, Director, IIT-Hyderabad, India

Harada, Hiroshi, Professor, Kyoto University; Program Manager, ImPACT Program of Council for Science, Technology and Innovation, Cabinet Office (CAO), Japan Science and Technology Agency (JST), Japan

Matsuoka, Satoshi, Director, RIKEN Center for Computational Science (R-CCS), RIKEN; Professor, Department of Mathematical and Computing Sciences, Tokyo Institute of Technology, Japan

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

Thomsen, Christian, President, Technische Universität Berlin, Germany

Wilkinson, Ross, Executive Director, Australian National Data Service; Co-Chair, Research Data Alliance Council, Australia

Opening Remarks

Chair: Petit, Antoine

The chair opened the session by explaining that while big data brings tremendous opportunities, it also poses serious dangers to individual freedoms, privacy and the guarantee of a certain anonymity. He posed the question of whether an Intergovernmental Panel on Big Data needs to be created to consider these critical global issues.

The session speakers were then invited to offer comments. The speakers first noted that quality of data and providence of data are both crucial. Current best practice is FAIR (Findable, Accessible, Interoperable, and Reusable) data. However, it was suggested

that one of the biggest issues is trust of data, requiring partnerships. It was pointed out that the culture of research is to not share data, but it was suggested that there is a need for data marketplaces, with protocols and processes around quality management.

Next, the speakers considered the coming explosion of IoT devices that will be connected to the Internet, each with various sensors generating data, which requires a rethink in terms of the quantity and type of data that will be available, including concerns over validation and management. It was suggested that the STS *forum* is the right place to elaborate a protocol for data sharing.

The speakers then discussed how health data from the national health service in Japan is being used to create country-wide time series data to create models for health forecasting and analysis. Some of the challenges were shared, including the difficulties in the preparation of big data from health records, and the tradeoff between securing remote devices using encryption and the high power requirements of secure encryption processes.

Next, the speakers discussed how the massive advances in computing power resources had enabled AI and big data techniques, such as in the case of genome sequencing, which became possible once computing power made the already existing data and algorithms usable. It was suggested that there are many further areas in which data which is not currently usable may become useful in the future but requires further great advances in computing power and efficiency.

The speakers also discussed lessons from CERN's LHC, where the quantities of data generated are too large to be stored, and would also overwhelm the existing networks of datacenters. Addressing this required triggers in edge computing to process and intelligently filter data before it is stored. In addition, it was noted that applying AI techniques considerably accelerated the work done at the LHC, resulting in huge budget savings.

The speakers also noted that AI and big data would gradually become necessary to remain competitive in all fields of science, but that this comes with the burden of learning data science techniques, and universities are not yet all set up to provide teaching in data science alongside primary subjects.

Discussion

Following the opening remarks, a group discussion was held. The participants first considered who owns data, the importance of data sharing, and what a protocol for data sharing might look like. Additionally, the participants considered examples of disputes over data ownership in different industry segments, and suggested that regulation is necessary in this area. Furthermore, it was suggested that ethical aspects around data usage should be considered, with policies and regulations put in place to ensure basic protections. On the other hand, it was felt that sharing of data between fields should be encouraged, and appropriate incentives should be considered. To facilitate this, it is also important to consider the interoperability and long-term usability of data, as well as aspects such as the effects of filtering of data, and the repeatability of analysis of data to generate results. The participants discussed the challenges of defining international standards for data sharing given the huge differences in data across different fields, and concerns were noted about the natural incentive to not share data that has commercial value in order to gain competitive advantage, and further consideration is needed to overcome this issue. There was also some discussion about challenges of selection of valuable data that should be retained, and whether data should be given an expiry date. Finally, the participants discussed the challenges of funding in the world of big data, and how the nature of research may be fundamentally changed by the impacts of big data.

Social Infrastructure
New Transportation Systems

[Chair]

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.

[Speakers]

Paola-Galloni, Jean-Luc di, Operational Vice-Chairman, European Road Transport Research Advisory Council (ERTRAC), Belgium; Vice-President for Sustainability and External Affairs, VALEO, France

Pieh, Silja, CFO & Head of Product, Autonomous Intelligent Driving GmbH, Germany

Samanta Roy, Robie I., Vice President, Technology Strategy and Innovation, Corporate Engineering, Technology and Operations, Lockheed Martin Corporation, U.S.A.

Sperling, Daniel, Distinguished Blue Planet Prize Professor of Engineering and Environmental Science and Policy, and Founding Director of the Institute of Transportation Studies, University of California, Davis, U.S.A.

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

Chair: Kikuchi, Noboru

Opening Remarks

The chair opened the concurrent session by explaining the importance for this session to discuss technologies of new transportation with social infrastructure and to discuss the challenges and less desirable points that have to be addressed; and the perspective of each person owning and driving a car requires a lot of space to accommodate the car, parking, and traveling on the highway. Finally, the chair noted that the sustainable development and efficient use of new technologies are necessary in order to take full advantage of the benefits that autonomous vehicles (AVs) can provide to us.

The session speakers were invited to offer comments. Discussions began with acts of the automation and electrification of vehicles including the introduction of automation in the form of self-automated personal transport, for example, linking a parking lot to a terminal at Heathrow airport. Also, the speakers discussed park assist systems and the utilization of connectivity to change land use related to parking by removing the vehicles that are looking for parking spots.

The issues surrounding autonomous vehicles (AVs) were discussed. These included the challenges with sensors and computing power, the affordability of providing redundancy in AVs, the need for more expertise in software algorithms, and the necessity for infrastructure and legal framework to align. Questions were then presented to spark conversations which involved the public perception of AV safety.

Following that, the speakers discussed the framework behind understanding how the AV systems will sense their environment, and how they will decide and act. The speakers emphasized that digitization and communication between these systems are very important, and the importance of how governments deal with risk and the public's perception.

The speakers also addressed the transformation that electrified and automated vehicles will bring about. Automation, electrification, and pooling will reduce the cost of transportation, and transportation could be provided virtually to everyone. On the other hand, if people use AVs in the same way that we use cars now, then car use will increase by 50% to 100%, so the speakers emphasized that a change in people's mindset needs to change.

Another subject was the transportation infrastructure in Malaysia. Since transportation systems are getting more expensive, it is very difficult for them to provide new transportation systems to most parts of the county. The speakers also discussed what the Malaysian government is doing to enhance their transportation infrastructure and capabilities.

Discussion

Following the opening remarks, a group discussion was held. The participants touched upon different innovations in the mobility space, like paint and coating which are easily detected by sensors, semiconductor components in cars, parking lots which enhance convenience, the benefits of AVs, a seamless payment system across all forms of transportation, transportation infrastructure policies, the changing of the ownership mindset, and usage models including the legal aspect of who owns the data.

There was also discussion from the point of view of original equipment manufacturers (OEMs) on many factors including manufacturing, specific road and traffic systems which support AVs, where to start putting AVs to use, the large amount of money that is being invested into AVs and how to collaborate research in the areas of connectivity, the amount of cars which need to be implemented in order to make an impact on traffic congestion, and the feeling of safety riding in AVs.

The participants then highlighted air technology involving personal air transportation, the feeling of safety in autonomous helicopters, the lack and lag of regulation surrounding personal air transportation, the necessity of air transport, the overall mindset of a high fatality rate in case of accidents, and space exploration not only for human travel but also for carrying out other tasks like deliveries.

Another point was the importance of the technical sides of pooling and sharing, who can establish social systems and policies, and the chances for innovations and room for improvements. The risk of creating negative outcomes from AVs and the challenges of the improvement of social transportation systems were noted.

Lastly, participants presented opinions on how to make the new systems affordable and sustainable, the root cause of affordability and sustainability, what is happening with issues surrounding ride-share companies and taxis, the mindset of using personal cars versus public transportation, a platform for regulators to communicate collaboratively, a platform for sharing data among industry players, the need to establish a consortium to promote collaboration, and seamlessness from one form of transport to another with regard to pay systems.

Social Infrastructure
Smart and Resilient Cities

[Chair]

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

[Speakers]

Blackwell, Theo, Chief Digital Officer, Greater London Authority, U.K.

Fink, Jonathan, Professor of Geology, Portland State University (PSU); Visiting Professor of Urban Analytics, Department of Earth, Ocean, Atmospheric Sciences (UBC), University of British Columbia, Canada

Gertler, Meric S., President, University of Toronto, Canada

Minamide, Traci j., Chief Operating Officer, LA Sanitation and Environment, City of Los Angeles, U.S.A.

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

Sameshima, Shigetoshi, General Manager of Center for Technology Innovation and General Manager of Yokohama Research Laboratory, Research & Development Group, Hitachi, Ltd., Japan

Chair: Mazur, Eric

Opening Remarks

The concurrent session was opened by the chair by explaining megacities. Specifically, the chair emphasized that urbanization and the amount of megacities around the world are increasing. Megacities are the hub of society, but they cannot sustain themselves without relying on the resources from the countryside around them. Megacities cause great strain on the environment, such as through pollution and energy consumption. The chair expressed his desire for the participants to discuss how to improve life in cities in this session.

After the opening, the session speakers were invited to share their comments. They began by describing what cities can do to accommodate overcrowding, the trade-off of having smart and resilient cities, the relationship between megacities and cities with regard to their universities, and what megacities should do to be more resilient.

The speakers also talked about how cities could use technology to progress. Some key points were the challenges faced by city governments, their residents, and companies in choosing which technologies to try, and the role of inter-sectoral exchange, regional collaboration, and networks of campus testbeds in facilitating these decisions.

The issues surrounding smart and resilient cities were further discussed by describing how economic, social, and political stability will be tied to success of cities, and universities will play a critical role in the process; and the more a university does to make improvements in its city, the easier it is for them to attract better professors and students.

Following that, the speakers explained the importance of water resiliency. Some cities do not have enough water to accommodate their population, so they have to bring water in from other sources. This process increases the carbon footprint of the city, so it is vital for cities to become moderately sufficient in terms of water.

The speakers then addressed factors such as people in less developed areas moving to more developed areas and causing a lot of negative effects; and global mobility and sustainable traffic are key issues that need to be worked on together in order to find solutions.

Finally, the speakers concluded the opening remarks by explaining the importance of achieving consensus between stakeholders to construct smart cities. Past projects to make cities smarter showed that it is critical to achieve consensus, but how to achieve consensus is the next issue to address.

Discussion

A group discussion was held following the opening remarks. The participants mentioned that legal framework is needed for advancing cities, ideas about who owns the data of smart cities are needed, and there is a need for partnerships not only between the private sector and citizens but also universities and cities.

Then, the participants highlighted how to ensure that benefits of technologies reach residents of cities with a form of choice instead of being imposed, how different cities might have different priorities and choices, how to get city residences to make those choices, opportunities to allow people to test new technology to see if its benefits are worthy, and possibly using the learning we get from city to city with sister city partnerships in order to promote information sharing.

There was also a discussion about the importance of connectivity within cities because smart cities are based on connectivity. Participants discussed resiliency against natural disasters and the different needs of each city; and collaboration between universities and cities having a lot of impacts on different parts of society including the private sector, citizens, the economy, society, and politics.

The participants continued to discuss what to do with obsolete technologies and how to recycle them in the wake of adopting new technologies, legislation in terms of setting goals for actions, the importance of setting goals with actions, and the importance of thinking about the future impacts of using new technologies today.

Lastly, participants explained their ideas about how open information exchange can make cities more resilient, how cities can go beyond policies to take more actions, the need for connectivity in cities, the rights of citizens being connected, and the need to support ideas of common solutions by having open platforms and data sharing.

Social Infrastructure
Advanced Agriculture and Food Industries

[Chair]

Saovapruk, Yongvut, President, National Food Institute, Ministry of Industry, Thailand

[Speakers]

Floros, John, President, New Mexico State University, U.S.A.

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

Kyuma, Kazuo, President, National Agriculture and Food Research Organization, Japan

Noguchi, Noboru, Professor, Research Faculty of Agriculture, Hokkaido University; Program Director, Cross-ministerial Strategic Innovation Promotion Program (SIP) "Technologies for Creating Next-Generation Agriculture, Forestry and Fisheries", Bureau of Science, Technology and Innovation, Cabinet Office, Government of Japan, Japan

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

Varas, Samuel, Director, Information Technology Division (CIO), Food and Agriculture Organization (FAO), Italy

Opening Remarks

Chair: Saovapruk, Yongvut

The chair opened the concurrent session by emphasizing the importance of connectivity between agriculture and the food industry. The fact that the number of global trends are threatening food security was explained. The need to reduce famine, water pollution, and disease was also emphasized. In addition, the chair discussed the environmental factors, such as using less energy and pesticides in the industry to lower greenhouse gases. Finally, the chair mentioned that local and community leadership, changes in behavior, action, and new requirements for automation are necessary.

The speakers were invited to share information about advanced agriculture and food industries. They started by discussing scientific breakthroughs in science and agriculture. The focus on these breakthroughs was on the improvement of efficiency, resiliency, and sustainability. A point was raised that stated data science and information technology can and should be applied to agriculture, however, they need management in order take advantage of the benefits.

Next, the speakers mentioned the possibility that the population may stabilize but looking at technologies for sustainability is still necessary. The need for greater resources is apparent for sustainability. They also talked about how there are trade-offs between growing vegetables and raising meat, how animal waste should be managed through biogas and fertilizer, and how vertical agriculture and hydroponics should be used more.

The speakers discussed Society 5.0, a concept that aims to achieve economic growth while at the same time solving social issues through integrating physical-space and cyber-space. Also, the speakers talked about the initiatives taken by NARO (the National Agriculture and Food Research Organization) to realize Society 5.0 in the agriculture and food sectors in Japan. In particular, the roles of ICT and AI technology in strengthening agriculture and food research were discussed in detail.

The speakers continued the discussions by explaining the challenges that will be faced in sustainable agriculture in the future. For example, the amount of farmers in Japan is declining, and climate change is exacerbating issues. The speakers also talked about the use of automation in the industry to, for example, increase the production of rice per hectare.

The speakers provided insightful ideas about the profound impact that the agriculture and food industry has on the globe, the challenge of reducing carbon emissions from food production, and the appropriate use of fresh water for food production. In addition to environmental impacts, the job market is also affected and economic migration is a strong factor in agriculture.

Finally, the speakers discussed what kinds of changes technology growth in agriculture will bring, the ICT in the agriculture and food industry, the social and environmental costs due to food production, and the imbalance in the food system. In addition to those topics, the future of the industry was discussed, such as which areas should be focused on, the integration of digital agriculture, and the potential to make agriculture more sustainable and efficient.

Discussion

Following the opening remarks, the participants held a group discussion. The participants talked about the digital connectivity issues in farming, being better at predicting market prices and weather patterns, the issue of aging populations, issues of soil erosion, and the lack of genetic diversity in crops.

The participants also discussed how to apply technology to agriculture, how to connect data to the food chain from the farm to the table, the bio economy and which parts of the plants are the best to consume, the movement of young people going back to the farm, sharing data information and policies related to it, education and support from the government, the use of AI support, and care being taken not to lose biodiversity of crops.

The participants touched upon different kinds of agriculture technologies, the collection of data which requires processing capabilities and provides great challenges, the positive effects of subsidizing agriculture for technology and production, and the difficulties to convince farmers to use technology.

The Society 5.0 initiatives were discussed from technical and social viewpoints. Participants agreed with the point that analysis of agri-food big data by AI technology and wider

applications of ICT and robotics would contribute to sustainable agriculture and food production. Issues related to data sharing, data regulation, and fostering AI literacy in terms of realizing Society 5.0 in agriculture and food sectors were also discussed.

Finally, participants focused on the food aspect of the industry. There are problems with distribution and consumption of food because there are still malnutrition issues. Food production also differs across regions, so there may not be a global solution. Another big issue that was touched upon was food waste, such as the amount of waste in food production. In the end, the push to implement technology which improves production was emphasized.

Statement

1. The 15th Annual Meeting of the Science and Technology in Society *forum* took place from October 7 to 9, with the participation of more than 1,400 global leaders in science and technology, policy-making, business, and media from nearly 80 countries, regions, and international organizations.

2. Science and technology issues concern all of us, and they should not be left only to science and technology professionals. We must all think of them as our own problem. Open science encourages the broader participation of other scientists as well as citizens, reinforcing the idea of open societies. The problems also cannot be solved by one or two countries alone, and therefore it is important for scientists, policy makers, business executives, and other leaders to gather and discuss the issues. Beyond that, effective communication of science and research findings to the public, thereby encouraging better understanding and greater participation of stakeholders as science and technology continue to transform society.

3. For the 15th anniversary of the STS *forum*, we had a special plenary session on the "Lights and Shadows of Science and Technology" reviewing the past 15 years to advance the discussion for the next 15 years. Even in this short span of time, the speed of innovation has been astounding, leading to exciting developments in science and technology. Our foundational concept of strengthening the lights and controlling the shadows remains unchanged, but we must now focus on new areas pioneered by scientific progress. The STS *forum*'s role in encouraging dialogue and actions on science and technology and the future of humanity is more important than ever.

4. Based on discussion at the STS 15th Annual Meeting, we would like to highlight the following points.

Energy and Environment

5. Lowering emissions remains a global priority. Harnessing existing and emerging scientific and technological knowledge for new energy solutions will be essential to rapidly reach a Net Zero Emissions future. Although global investment in renewable energy was on the decline last year, technical innovations improved the efficient management of energy supply and demand. As we move toward the continued reduction of carbon in our economies, improving energy storage technologies will be key for the further development of electric vehicles and other innovations. While new sources of renewable energy are absolutely needed, nuclear energy remains a critical source for energy generation under strict conditions of safety, security, and non-proliferation.

6. Despite prior efforts to mitigate climate change, some nations are not achieving their Nationally Defined Contributions, leading to projections consistent with a 3 or 4°C temperature increase rather than the 2°C predicted. In a drastically changing environment, we can expect even more extreme weather events and other hazards, including rising sea levels. We must reinforce the global efforts to meet these global challenges. We should urgently enhance the collection, storage, analysis, and deployment of scientific knowledge on space, earth, and oceans to monitor the effects of our actions on the environment and to estimate the likely consequences. This should help us better design our programs for mitigating and adapting to climate change.

Life Sciences and Healthcare

7. Progress in the new genetics has opened new doors for human gene-based therapy. Genetic science can also enhance food security when applied to plant cultivation and animal breeding. As we move in these directions, it is essential that there be a broadly based societal discussion on the ethics and legal aspects that should govern the application of this new technology to humans.

8. While life expectancy is increasing worldwide, the incidence of age-related diseases is also increasing. The rapid development of science and technology in advanced and preventive medicine provides new opportunities to support healthy aging.

9. The fight against infectious disease is still a global mission. We must continue to make an effort to build an international system to help nations deliver good health care to all parts of the world with the cooperation of WHO and other organizations.

Digital Society

10. Robotics, machine-human interaction, Artificial Intelligence, the Internet of Things, and Big Data analytics offer opportunities for changing production processes, the conduct of economic activity, and many other aspects of our lives. Other promising technologies include blockchains (subject to curbing their enormous energy consumption), quantum computing, and novel applications for Augmented Reality and Virtual Reality. Global cooperation and joint projects among governments, industries, and academia on standards and security measures are needed even as we move towards more Open Science and even the promotion of co-creation with stakeholders and SMEs. At the same time, we need to manage job disruption and protect society against the misuse of personal data. Preserving individual freedoms, respecting privacy, and guaranteeing a certain degree of anonymity must be the rule.

Research and Innovation

11. Education is going through a revolution, not just in terms of content but also in terms of teaching methods and the incorporation of ICT throughout basic schooling, university, and graduate studies, with its potential to provide much wider access to an excellent education around the globe. The role of universities must include both the advancement of science and technology as well as concern with the Ethical, Legal, and Social Issues associated with these advances.

12. Environmental concerns and sustainability should be the most important forces driving industrial innovation. The costs of pollution and excessive resource depletion should be factored into all of our economic strategies, and governments should create the frameworks that will induce economic actors to take these into account.

13. The challenges for the food and agricultural industries with respect to the international community are related to initiatives for improving food security through smart and integrated production. This includes incorporating ICT and other leading-edge technologies, including the breeding and engineering of plants to be more salinity and

drought resistant with a shorter growing season and with greater resistance to suffering post-harvest losses. It is essential that each country make an effort, through policies, initiatives, and concrete strategies, to tackle technical problems in smart agriculture, to encourage high value urban agriculture and hydroponics, and to help develop a highly productive food industry under a sustainable development agenda.

Cooperation in Science and Technology

14. Science is increasingly moving toward an open framework for knowledge exchange, protected by appropriate intellectual property rights and increasingly encouraged by governments with policies for Science, Technology, and Innovation. The links between peoples will increasingly require that a greater role be given to S&T diplomacy in a world where many tensions still exist and all could benefit from more harmonious scientific cooperation and exchanges.

15. Although the challenges are great, human intelligence and innovation are up to the task of finding appropriate solutions. It is essential that academia, governments, and industry promote a climate for innovation and the legal framework that will encourage the transformation of new ideas into viable and sustainable enterprises that benefit society and the environment we all depend on.

16. We look forward to meeting here again next year and have agreed to hold the 16th Annual Meeting of the STS *forum* in Kyoto from Sunday, October 6 to Tuesday, October 8, 2019.

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STS *forum* 2018 Summary – 15th Annual Meeting
Issued by Koji Omi
Edited by Science and Technology in Society *forum* (STS *forum*)
Sanno Grand Building 419, 2-14-2 Nagatacho, Chiyoda-ku, Tokyo 100-0014, Japan
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