21st Annual Meeting

STS *forum* 2024

Summary

October 6, 7 and 8, 2024
Kyoto, Japan

Science and Technology in Society *forum*

Summary of STS *forum* 2024

STS *forum* 2024 - 21st Annual Meeting

October 6-8, 2024

Plenary Sessions | Concurrent Sessions | By Invitation Only

October 5, 2024 (Saturday)

10:00-18:30	Registration (ICC Kyoto) (for all STS *forum* participants)	11:00-12:30	AA-STS Board Meeting
		11:30-18:35	Regional Action on Climate Change (RACC16) [Room A]
		12:00-12:50	Young Leaders Network
		12:50-15:30	Dialogue between Young Leaders and Nobel Laureates
		13:30-15:00	Board Meeting
		14:00-16:40	Kyoto Symposium
		14:00-17:00	13th Global Summit of Research Institute Leaders
		16:00-18:00	Forum for Unity, Science, and Empowerment (FUSE)
18:00-20:00	Networking Plaza [Sakura, ICC Kyoto]		

October 6, 2024 (Sunday)

08:30		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)			
10:00-11:00 60 min.	100	**Opening: The World in 2024 -- What do we need from S&T? [Main Hall]**			
11:00-12:00 60 min.	101	**Path to Sustainability [Main Hall]**			
12:00-13:50 110 min.		Lunch and Networking Time [Sakura]			12:10-13:30 CEO Meeting 12:10-13:30 CTO Meeting 12:10-13:30 University Presidents' Meeting 12:10-13:30 Heads of Private Foundations Meeting 12:10-14:50 S&T Ministers' Roundtable
13:50-14:50 60 min.	102	**Koji Omi Memorial Plenary: Lights and Shadows of AI [Main Hall]**			
14:50-15:10		Coffee Break			
15:10-17:10 120 min.	103	Energy	Earth and Commons	Climate Risks	Life Sciences
		Action for Net-Zero Emission [Room B-1]	**Digital Twins of Ocean [Room K]**	**Resilient Society against Climate Risks [Room B-2]**	**AI for Health [Room D]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Technologies
		Revolutionary Materials and Devices [Room C-1]	**Science and Technology Diplomacy [Room C-2]**	**Fostering New Generations of Scientists with Inclusion and Diversity [Room E]**	**Countering Disinformation in Digital Age [Room A]**
17:10-17:30		Coffee Break			
17:30-18:30 60 min.	104	**104A: Basic Science, Innovation and Policy [Main Hall]**		**104B: Science and Technology for Business [Room A]**	
18:30-		Move to the venue, Cocktail			
19:00-21:00	105	Official Dinner [Event Hall]			

October 7, 2024 (Monday)

07:30		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)			08:00-08:45 General Meeting
09:00-10:10 70 min.	200	**AI Ethics and Regulation [Main Hall]**			
10:10-10:40		Coffee Break			
10:40-12:40 120 min.	201	Energy	Earth and Commons	Climate Risks	Life Sciences
		Investment and Financing for Energy Transition [Room B-1]	**Food and Water Security [Room K]**	**Adaptation to Climate Change [Room B-2]**	**Breakthrough in Biotechnology [Room D]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Technologies
		Quantum Science and Technologies [Room C-1]	**Collaboration among Academia, Industry and Government [Room C-2]**	**AI in Education [Room E]**	**Cybersecurity [Room H]**
12:40-14:20 100 min.		Lunch and Networking Time [Sakura]			12:50-14:10 Academy of Science Presidents' Meeting 12:50-14:10 Academy of Engineering Presidents' Meeting 12:50-14:10 Funding Agency Presidents' Meeting
14:20-16:20 120 min.	202	Energy	Earth and Commons	Demography	Life Sciences
		Solutions to Renewable Energy Intermittence [Room B-1]	**Circular Economy toward End of Mining [Room K]**	**Declining Population [Room B-2]**	**Patient Advocacy [Room D]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Technologies
		Green Technologies [Room C-1]	**Nurturing Innovation-based Startups [Room C-2]**	**Signaling the Trustworthiness of Science [Room E]**	**Sensor Technologies [Room H]**
16:20-16:50		Coffee Break			
16:50-18:00 70 min.	203	**203A: Global Health [Main Hall]**		**203B: Shaping the Future of Higher Education [Room A]**	
18:00-		Move to the venue (Shuttle bus provided from ICC Kyoto to site)			
19:00-21:00	204	Special Buffet Dinner at Hotel Okura Kyoto			20:30-22:00 Council Meeting

October 8, 2024 (Tuesday)

08:00		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)
09:00-11:00 120 min.	300	**Takeaways from Concurrent Sessions [Main Hall]**
11:00-11:40		Coffee Break
11:40-12:30 50 min.	301	**Closing: Science and Technology for the Future of Humankind [Main Hall]**
12:30-13:30	302	Farewell Buffet Lunch [Swan]

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Plenary Sessions

Opening Plenary Session: The World in 2024 -- What do we need from S&T?

[Chair]

Komiyama, Hiroshi, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman, Mitsubishi Research Institute, Inc., Japan

[Video Message]

Ishiba, Shigeru, Prime Minister, Government of Japan, Japan

[Speakers]

Isarabhakdi, Supamas, Minister, Ministry of Higher Education, Science, Research and Innovation, Thailand

Eldesouki, Munir M., President, King Abdulaziz City for Science and Technology (KACST), Saudi Arabia

Yoo, Sang-Im, Minister, Ministry of Science and ICT, Korea

Zuber, Maria T., Presidential Advisor for Science and Technology Policy (PASTP), E. A. Griswold Professor of Geophysics, Massachusetts Institute of Technology (MIT); Co-chair, President's Council of Advisors on Science and Technology (PCAST), The White House, U.S.A.

Brandenburg, Jens, Parliamentary State Secretary, Federal Ministry of Education and Research, Germany

Komiyama, Hiroshi

Opening Remarks

Prof. Hiroshi Komiyama, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman, Mitsubishi Research Institute, Inc., opened the 21st Annual Meeting of STS *forum*. Prof. Komiyama expressed his sincere appreciation to the participants for their attendance as well as sponsors, members, and organizing supporters for their contributions. STS *forum* was founded over 20 years to bring together academic, political, and business leaders to discuss the lights and shadows of science and technology from a long-term perspective. The significance of STS *forum* has only continued to grow.

Science and technology have driven rapid progress since the 20th century, yet humanity now faces numerous challenges that cast dark shadows on society. Climate change stands as a critical issue, with the Earth's average temperature increasing by 1.5 degrees Celsius compared to the previous year. This could be a devastating trend if it continues.

Whether humans continue to flourish or our society heads towards disaster will depend on our own actions. Potential solutions include non-fossil-fuel energy sources and the concept of saturation, whereby manmade objects can be recycled and recirculated, making it no longer necessary to dig up underground resources. At the same time, important social issues like food shortages and war still require attention.

Another hope lies in humans' great store of knowledge. All problems can be resolved, provided the right knowledge is applied. However, human knowledge is fragmented, like the spines of a porcupine fish. Science and technology can help bridge the gaps between fragments of knowledge, extract their essence, and integrate them in ways previously unimagined.

Every technological advancement can have bright and dark sides. This is particularly true of generative AI. In recognition of the great transformative power of generative AI, STS *forum* has decided to collaborate with a specialized AI team to transcribe and display summaries of sessions of this year's Annual Meeting almost in near real-time using generative AI. STS *forum* is a unique opportunity for leaders from politics, business and academia to discuss the long-term impact of science and technology, including both its lights and shadows, and such an experimental collaboration between these human leaders and AI is particularly significant. Science and technology have the potential to bring humans a disastrous future but equally to bring a brighter future for humankind, and leaders have a responsibility to guide science and technology towards the latter.

One initiative that seeks to do this is the Platinum Society, which aims to achieve a sustainable world and a prosperous society where all can achieve self-actualization and is producing early signs of change in Japanese society. Likewise, the diverse leaders at STS *forum* must take action to effect transformation. Their discussions at STS *forum* will hopefully transcend national boundaries and fields of expertise, paving the way for a brighter future.

Mr. Shigeru Ishiba, Prime Minister, Government of Japan, welcomed the participants to the meeting via a video message. Prime Minister Ishiba emphasized the importance of

Ishiba, Shigeru

STS *forum* hosting discussions on science and technology in society among a group of eminent scientists, business leaders, politicians and policymakers from around the world.

A particularly prominent development in science and technology has been the recent rise of generative AI. Generative AI has brought revolutionary changes in various sectors, but it also poses risks such as misinformation and privacy concerns. Japan played a leading role in establishing the "Hiroshima AI Process Comprehensive Policy Framework," which led to agreement among the G7 agreement to pursue the goal of "safe, secure and trustworthy AI."

One side-effect of the widespread use of generative AI is the increasing power consumption of data centers. This necessitates innovation to balance energy demand with climate change mitigation. Japanese industry, government, and academia are working together on production, research and development, and human resource development for advanced semiconductors. Japan has also formulated national strategies on innovation in fusion energy and quantum technology. Through these efforts, Japan intends to drive innovation and resolve social issues, including the realization of a carbon-neutral society.

International research cooperation and science diplomacy are also crucial in the face of geopolitical instability and emerging technologies. Furthermore, talent plays a key role. Japan will accelerate the international exchange of research talents while ensuring research security and integrity.

The upcoming Expo 2025 in Osaka, Kansai, whose theme is "Designing Future Society for Our Lives," will be a testbed for showcasing cutting-edge technologies. The path to a better future for humanity starts with global leaders of science and technology openly sharing their visions and fearlessly striving ahead to make them a reality, and it is hoped that STS *forum* and the Expo will serve as starting points for envisioning a future society driven by science and technology and generating further innovations.

Ms. Supamas Isarabhakdi, Minister, Ministry of Higher Education, Science, Research and Innovation, Thailand, spoke about Thailand's efforts to promote sustainable development and climate action. Minister Supamas noted that the world today is facing rapid changes, transboundary environmental issues, and loss of biodiversity. Thailand is committed to addressing these issues and recognizes that collaboration among different sectors is essential.

Thailand has established a national strategy that aims to transform the country into a hub for the digital economy, green technologies and future mobility. The Ministry of Higher Education, Science, Research and Innovation plays a pivotal role in driving such transformation by fostering a highly skilled workforce, strengthening the grassroots economy, promoting sustainable self-reliance, and adapting to the dynamic global landscape. The Ministry is devoting particular effort to AI development and AI education, as well as responding to the climate crisis. Thailand has set two ambitious targets to achieve carbon neutrality by 2050 and

Isarabhakdi, Supamas

zero greenhouse gas emissions by 2065. Meanwhile, the Association of Southeast Asian Nations (ASEAN) has committed to achieving net-zero emissions through efforts such as solar energy development.

Nonetheless, technology alone cannot solve such complex challenges. It is essential to invest in science, technology, engineering, and mathematics (STEM) education to prepare the next generation with the skills to solve future problems. Such solutions also require collaboration for joint action and knowledge-sharing nationally, regionally, and globally. Through such efforts, science and technology can guide human society to a sustainable and equitable future.


Eldesouki, Munir M.

Dr. Munir M. Eldesouki, President, King Abdulaziz City for Science and Technology (KACST), Saudi Arabia, explained how Saudi Arabia is leveraging science and technology for sustainable solutions to global challenges. Dr. Eldesouki pointed out that the world faces immense challenges and unprecedented opportunities that science and technology are uniquely positioned to address. Saudi Arabia recognizes the importance of science and technology for shaping the future and therefore positions research, development and innovation as a central driver for achieving sustainability, economic growth and global collaboration under the country's Vision 2030.

Climate change and food security are among the pressing global issues. In response, Saudi Arabia is developing renewable energy technology and advancing carbon mitigation techniques, including the world's largest green hydrogen facility and carbon capture facilities. Saudi Arabia aims to not only slow climate change but also build resilient systems.

Saudi Arabia's initiatives extend beyond national priorities to contributing to global sustainability and well-being. These include combating diseases like dengue fever through sustainable biocontrol technologies and applying space technologies such as Earth observation to preserve scarce resources.

Recognizing that global challenges demand international cooperation, Saudi Arabia is also committed to strengthening partnerships within the region and globally. This includes building collaborative networks among scientists, entrepreneurs, industry leaders, and venture capitalists.

In addition, Saudi Arabia recognizes the importance of youth and investing in educating young generations of scientists and providing youth with the skills to drive digital transformation. Another important effort is its smart cities initiative, which is laying the groundwork for cities that are not only technologically advanced but also environmentally sustainable. Saudi Arabia will also host the Riyadh Expo 2030, showcasing how advances in science and technology can transform the world for the better. This event will demonstrate how shared efforts today can shape a different tomorrow.

Yoo, Sang-Im

Prof. Sang-Im Yoo, Minister, Ministry of Science and ICT, Korea, extolled the importance of international cooperation in science and technology. Minister Yoo began by highlighting global challenges such as rapid advances in AI and associated safety issues, pandemics, and environmental problems that no single country can tackle alone.

Korea has initiated several efforts to promote international cooperation. The New York Initiative emphasizes the need for a new order in the era of deepening digitalization. Korea's proposals led to the establishment of the United Nations' Digital Bill of Rights, which outlines five principles for a digital society of shared prosperity: freedom, fairness, safety, innovation, and solidarity. At the Seoul AI Summit, the Seoul Declaration was adopted, focusing on AI safety, innovation, and inclusivity while encouraging international collaboration. The growing importance of AI and digital tools in daily life has raised concerns over data privacy, security, and potential negative impacts, necessitating international cooperation to address these issues.

Such collaboration is also essential for tackling climate change, which poses a serious threat to ecosystems, economies and survival of human society. The international community must

prioritize carbon neutrality and sustainable economies, a responsibility shared across all countries and generations. Korea is actively developing climate change response technologies and fostering international cooperation in this area. Additionally, pandemic preparedness remains crucial, as future outbreaks are inevitable. Countries must share information and secure stable global supply chains. Korea is promoting exchanges for rapid disease response, securing resources, and supporting research to enhance response capabilities.

In addition, the international community must strengthen collaboration in response to pandemics, which are not threats of the past but will surely strike again in the future. Countries must share information and secure stable global supply chains for tackling them. Korea is promoting exchanges for rapid disease response. It is also securing resources for that purpose, while also supporting research to enhance response capabilities.

Korea has also announced a Global R&D Strategy, committing approximately 4 billion USD to global R&D. The country plans to ensure effective utilization of these funds through strategic approaches, effective research management systems, and joint exchange and collaboration.

Zuber, Maria T.

Prof. Maria T. Zuber, Presidential Advisor for Science and Technology Policy (PASTP); E.A. Griswold Professor of Geophysics, Massachusetts Institute of Technology (MIT); Co-chair, President's Council of Advisors on Science and Technology (PCAST), The White House, U.S.A., emphasized the critical role of science and technology in addressing global challenges. She highlighted the interconnected nature of these issues and the need for worldwide collaboration.

Prof. Zuber presented four examples of such challenges and potential solutions. Climate change, environmental sustainability, and energy demand require transforming global energy systems, moving away from fossil fuels, and rapid development of commercially viable renewable energy, among other solutions.

Global pandemics and healthcare access issues can be addressed through vaccine development, genomic medicine, telemedicine, AI-powered diagnostics, and bioengineering for new therapies. Basic research funding remains essential, as exemplified by the mRNA technology crucial in combating COVID-19.

The third challenge is food and agriculture, including global population growth, water scarcity, and climate-related disruptions. Solutions include precision agriculture, genetically modified crops, and aquaculture advancements, among others.

The fourth challenge is freshwater scarcity and parity, including global water shortages, pollution, and lack of access to clean drinking water. Solutions include desalination technologies, wastewater recycling, and advanced filtration and purification technologies.

The emergence of AI is critical in solving all of these problems, but AI also has associated problems related to the amount of energy and water used. One potential solution is designing chips powered by light rather than electricity. This would enable the full power of AI to be harnessed to address the aforementioned challenges and many more.

Brandenburg, Jens

Dr. Jens Brandenburg, Parliamentary State Secretary, Federal Ministry of Education and Research, Germany, spoke about the value of international cooperation in science and technology, highlighting examples of Japan-Germany collaboration. Dr. Brandenburg pointed out that there is so much that the world needs from science and technology and noted that most important is to find common ground and strengthen collaboration. He then cited three key points for doing so.

First is the strength to overcome crises, such as climate change. Germany has set an ambitious goal to become a hydrogen republic and has launched international joint research centers to that end around the world, including in Japan. Green hydrogen and fusion technologies are also important, and Japan is collaborating with the European Union on such efforts.

The second key point is sovereignty, particularly technological sovereignty. Issues such as COVID-19 and new wars have made many countries reexamine their existing practices. Geopolitics are constantly changing, making international relations increasing complex. That is precisely why it is important for a country to be considered a partner of another. Countries cannot neglect their commitments to freedom, independence and peace. In this regard, science diplomacy is an overarching element of Germany's national future and research strategy. Technological sovereignty should protect countries from dependency but should not isolate them.

The third key point is security. Science and technology underpin a country's security. At the same time, science and technology themselves rely on security to protect them from dangers such as external interference or theft. Research security is therefore a critical concern.

Path to Sustainability

[Chair]

Al-Khowaiter, Ahmad O., Executive Vice President, Technology & Innovation, Aramco, Saudi Arabia

[Speakers]

Rockström, Johan, Director, Potsdam Institute for Climate Impact Research (PIK); Professor, Institute for Earth System Science, University of Potsdam, Germany

Richmond, Geraldine L., Under Secretary, Science and Innovation, Department of Energy (DOE), U.S.A.

Brabeck-Letmathe, Peter, Chairman of the Board of Directors, Geneva Science and Diplomacy Anticipator (GESDA); Chairman Emeritus, Nestlé S.A., Switzerland

Abdool Karim, Quarraisha, President, The World Academy of Sciences (TWAS); Associate Scientific Director, Centre for the AIDS Programme of Research in South Africa (CAPRISA), South Africa

Opening Remarks

The session was opened by Mr. Ahmad O. Al-Khowaiter, who spoke about the multi-dimensionality of paths to sustainability. The sustainability of the planet affects all living things and global conversations for finding global solutions are needed. There are multiple paths to be followed through to sustainability. The scientific community needs to contribute knowledge to guide good policy, but what constitutes good policy depends on different societies.

Al-Khowaiter, Ahmad O.

One-dimensional solutions create divides among different countries that face differing constraints. Policies must also account for diversity of life on the planet and also diverse circumstances of different societies. The United Nations' Sustainable Development Goals (SDGs) provide an important framework for balancing and addressing such multi-dimensional issues.

While it is important to explore issues for future generations, we must not neglect the people of today. Many people have basic needs that

are unmet and that most of the rest of world takes for granted, such as enough food and a stable supply of electricity.

Prof. Johan Rockström explained the concept and framework of planetary boundary science. Researchers have identified nine earth systems that regulate the stability and health of the planet and have quantified safe boundaries that must be maintained to avoid an irreversible drift away from stable conditions.

Six of the nine systems are currently outside the safe operating space, offering a warning for humanity. This includes not only climate change but also the degradation of the integrity of the biosphere and over-consumption of freshwater, among other concerns. At New York Climate Week, the first planetary health check was launched, and such planetary health checks will be conducted annually. All six of the aforementioned systems are trending away from the safe operating space, leading towards deeper instability.

In planetary boundary science, there is a need to differentiate between fast and slow variables. Society tends to focus more on the fast variables such as climate change and associated disasters. However, there are also slow variables, such as the resilience of the Earth system and the capacity of the oceans and other systems to buffer and dampen stress.

Planetary boundary science is not only a guide for human development but also an accounting system to ensure stable conditions for the Earth system into the future. It offers a translation and operationalization opportunity for businesses, economies and policies. Human society must also initiate a paradigm shift, redefining sustainable development such that it entails not only reducing environmental impacts, but also ensuring development occurs within the safe operating space of the scientifically defined planetary boundaries.

Dr. Geraldine L. Richmond began by noting how dramatic changes to the world's ecosystems have led to heavy impacts on communities around the world. She then explained how the United States Department of Energy (DOE) is making great efforts to address the issues of energy security and decarbonization. The Department has undergone a reorganization such that it now encompasses not only basic and applied science research, but also has significant funding for investing in and deploying technologies.

Particularly notable is DOE's Energy Earthshots Initiative aimed at accelerating breakthroughs in clean energy solutions within a decade. The eight Earthshots are the Carbon Negative Shot, the Clean Fuels and Products Shot, the Enhanced Geothermal Shot, the Floating Offshore Wind Shot, the Hydrogen Shot, the Industrial Heat Shot, the Long Duration Storage Shot, and the Affordable Home Energy Shot. In addition, nuclear energy and fusion offer solutions as safe and carbon-free power sources.

In these and other efforts to protect our shared planet and preserve it for future generations, cooperation is critical. Science and technology offer humankind hope, but we must all work together.

Mr. Peter Brabeck-Letmathe emphasized the importance of anticipation as a key element of sustainability. Advances in science and technology are without a doubt accelerating, but not everybody benefits from these advances. Anticipation is essential for ensuring people can benefit more quickly and for achieving a more sustainable society. Anticipation means detecting and monitoring emerging science developments, increasing preparedness by speeding up early uses of scientific breakthroughs, and developing and funding early international trials to ensure that opportunities, benefits, and access are shared as soon as possible.

The speed with which generative AI has been developed and implemented has surprised most of the world. The next revolution, in quantum computing, will accelerate this even more. Therefore, it is important to start developing applications and algorithms for concrete use cases for quantum technology now, before the next breakthroughs are made. The Geneva Science and Diplomacy Anticipator (GESDA) set up the Open Quantum Institute for that purpose.

The Institute explores the potential for the use of quantum computing for accelerating the realization of the SDGs. It believes in the importance of democratizing the early understanding and early use of emerging science breakthroughs and enhancing the scientific literacy of people from different backgrounds, and is engaging in initiatives to those ends. GESDA will also be part of the Swiss Pavilion at Expo 2025 Osaka, Kansai, where it will

promote scientific anticipation as one of the key paths to achieving the SDGs and also the goal of the Expo, which is “Designing Future Society for Our Lives.”

Prof. Quarraisha Abdool Karim spoke about the transformative role of science in shaping a more inclusive and just world. Science and technology offer a universal language to build bridges between peoples of the world. There are currently multiple converging issues that challenge the world, including climate change, pandemics, natural disasters, wars and conflicts, and widening inequalities between the Global North and South.

To harness the power of science, it is critical to close the gaps in existing inequalities in knowledge generation. While AI holds promise for bridging equalities, in reality, it frequently widens the gap. For AI to be a positive tool, prerequisites include access to data, electricity, water and a skilled work force. However, many lower-income countries cannot access these AI enablers. Furthermore, wealthier nations dominate AI research and apply it to issues that are not immediately beneficial to lower-income countries dealing with more fundamental challenges such as food security and basic education. Without proper inclusive policies, AI will continue along its current trajectory.

Science academies play pivotal roles in research, policy, ethical considerations and public engagement, and could lead the way to a sustainable future. They have also been harnessing the power of the best scientists and fostering new generations of scientists. However, their efforts are also being undermined by rising instances of forcible displacement of peoples around the world, with displacement causing socio-economic problems and stripping countries of valuable intellectual assets. Peace is thus a prerequisite for sustainable development.

Addressing the complex issues that the world faces will require the integration of scientific understanding and policymaking. It will also take dialogue among diverse stakeholders. Only then can technological advancements contribute to the good of society at large, benefiting everyone everywhere.

Discussion

Mr. Al-Khowaiter asked which planetary boundaries have not received the attention they deserve.

Prof. Rockström answered that they are all interrelated but highlighted biodiversity loss as a critical issue that risks threatening food security and viral spillover from wildlife to humans.

Mr. Al-Khowaiter noted the growing resource demands of increasing uses of AI. He wondered how the use of necessary technology such as AI could be balanced with addressing emissions and climate-change-related challenges.

Dr. Richmond noted that the United States previously experienced a major spike in energy demand during the tech boom of the early 2000s. DOE was able to meet this rise with innovation and deployment. Energy demand continues to grow, and DOE has been working continually on ways to meet it for a long time. It will take time and it is challenging, but it can be done.

Mr. Al-Khowaiter asked which strategies and innovations are most critical for tackling food and water security.

Mr. Brabeck-Letmathe noted the need to increase food production by 70% by 2050, all while the resources needed for food production, such as arable land and water, continue to decrease. He believed that the only ways forward are through science and technology and efforts to reduce waste.

Mr. Al-Khowaiter asked how scientific institutions can play a bigger role in addressing issues of sustainability, particularly in developing countries.

Prof. Abdool Karim answered that science academies are essential to knowledge generation processes and to developing the skills base. They are also voices of trust that can influence evidence-based policymaking.

Furthermore, they must bridge inequalities through respect-based, synergistic partnerships and collaboration. The scientific community must also bring the population with them through earlier engagement in the scientific process.

Mr. Al-Khowaiter inquired how the Earth Commission builds collaboration across sectors and disciplines.

Prof. Rockström explained that the Earth Commission quantifies safe and just Earth system boundaries for humanity's future. This quantification is the first of its kind and represents a breakthrough in linking social sciences and the natural sciences to address sustainability issues in the Anthropocene.

Mr. Al-Khowaiter invited Dr. Richmond to share more examples of exciting initiatives at DOE.

Dr. Richmond mentioned that the United States is working to reduce greenhouse gas emissions to 50% below 2005 levels by 2030, achieve 100% carbon pollution-free electricity by 2035, and achieve a net zero emissions economy by 2050, noting the importance of the eight Energy Earthshots to these efforts. It is also working on de-risking potential solutions to the extent possible. Furthermore, 40% of benefits from DOE funding on renewables must go to disadvantaged communities.

Mr. Al-Khowaiter asked for further details on GESDA's efforts to promote scientific literacy among the public.

Mr. Brabeck-Letmathe explained that GESDA has published the GESDA Science Breakthrough Radar, which provides an overview of science trends and breakthrough predictions in the coming years. The public will be able to create its own future based on the data therein. GESDA has also developed a global curriculum for anticipatory leadership, aimed at fostering common language and better understanding among science, diplomacy, and politicians.

Mr. Al-Khowaiter asked about ways to develop talent pipelines, particularly in low-income countries.

Prof. Abdool Karim noted that such efforts are often focused on post-graduate education. However, it is also important to nurture curiosity and imagination in people from an early age. Greater efforts and continued investment in young people must be made to encourage them to imagine and dream up the solutions that will create a brighter future.

Koji Omi Memorial Plenary: Lights and Shadows of AI

[Chair]
Itoh, Kohei, President, Keio University, Japan

[Speakers]
Bess, Lane, Chief Executive Officer, Deep Instinct, U.S.A.
Delmolino, Dominic, Vice President, Worldwide Public Sector Field Technology & Innovation, Amazon Web Services (AWS), U.S.A.
Ojokoh, Bolanle, Professor, Department of Information Systems, Federal University of Technology Akure, Nigeria
Petit, Antoine, Chairman and CEO, National Center for Scientific Research (CNRS), France
Schill, Kerstin, Vice President, German Research Foundation (DFG); Professor of Computer Science, Institute for Cognitive Neuroinformatics, University of Bremen, Germany
Matsuo, Takehiko, Vice-Minister for International Affairs, Ministry of Economy, Trade and Industry (METI), Japan

Panel Discussion

The session was opened by Prof. Kohei Itoh, who welcomed the speakers and asked them to present their views on the lights and shadows of AI, beginning with the light side.

Mr. Lane Bess explained that, in the area of cyber security, AI has provided a way to battle threats to cyber security, including how deep neurological technology and deep learning can provide keys to combating cyber crimes and getting ahead of malicious intents. In the new revolution of AI, there are challenges, but more importantly, there are opportunities to fight fire with fire.

Itoh, Kohei

Dr. Dominic Delmolino commented that everyone is curious about the potentials of AI, particularly how generative AI can be used in a wide variety of areas, including creatively, allowing anyone to take advantage of the knowledge on the internet. AI has helped people understand complex topics, and these benefits will be transformative going forward.

Prof. Bolanle Ojokoh introduced the research she has been doing on AI, and how AI has tremendous capabilities and is continuously evolving. AI is capable of learning and solving problems, and can extract meaningful information from large and diverse sets of data. This also makes AI a beneficial concept in the areas of robotics, data mining, big data analytics, and applying deep learning to solve different problems in different domains. That is why it is important to delve into the potentials of AI, and reinforce them through education.

Prof. Antoine Petit stated that AI is an accelerator, making it possible to rapidly analyze large amounts of data in a way that humans cannot. AI can also be the origin of new models of paradigms of research, and enables science to tackle complex issues, such as climate change and diversity loss. Specialists from different areas will need to work together to train future generations on the use of AI. In the new AI era, we need to compare what AI was and what it is today, and it is clear AI produces fantastic opportunities for knowledge and development.

Prof. Kerstin Schill then discussed the possible effects of AI on scientific systems. Research is currently taking place at an unprecedented pace focusing on increasing processes of AI performance, but many AI systems have to be considered as complex systems. Scientists must consider how AI can influence people's understanding and make data available

from many scientific fields. Germany aims to support progress on AI, bringing multiple stakeholders together to maintain human networks and promote AI infrastructure in the long-term. AI can also be used in diverse disciplines to train systems to benefit humans. However, it is also essential to ensure that humans remain part of the system of change, and humans must consider the areas where AI should and should not be used.

Mr. Takehiko Matsuo commented that generative AI in particular has huge potential to transform the world's societies and economies. For example, as Japan faces a declining workforce, there is an imminent need to improve productivity, so it is essential for Japan to maximize the potentials of AI and promote innovation through AI. The world must strengthen human research development in the era of AI and Japan is securing human resources that can be used for AI development. Japan can continue to contribute to the world by honing its AI capabilities based on human resources.

Turning to the shadows of AI, Mr. Bess emphasized that the cyber domain is the biggest challenge of the day. Many cyber attacks utilize AI, and many governments and organizations use pre-existing systems that are unaccustomed to change. AI is taking advantage of the

weakest links, launching sophisticated and costly attacks. The key message is that it is essential to be vigilant and people must be willing to invest to prevent malicious attacks.

Dr. Delmolino added that there are specific issues with AI, such as the significant power needed to train AI and create large databases to feed generative AI models. But the larger the model, the more parameters there will be, meaning more equations and computing power requirements. There are ways to combat this, such as making use of the diverse range of AI models.

Prof. Ojokoh commented that AI has also been used to perpetuate misleading or false information. AI can also be deceived through using false data in a model, known as data poisoning. Other issues to overcome include differences in culture and fear over people being replaced with AI.

Prof. Petit added that data quality can lead to issues, but even if the AI is high in quality, they cannot take into account diversity in languages and interferences. This would mean that scientists have a responsibility to ensure that the data or output from AI can be proven.

Prof. Schill commented that we need to take the current development of AI more seriously. Humans and human experts must be involved in the decision-making process and be able to learn from mistakes. A simple inclusion at the end is too superficial. She reemphasized

the need for humans to be part of the AI decision-making process, and for humans to have a final decision on matters involving AI.

Mr. Matsuo commented that generative AI is still in its infancy. The Japanese government is introducing various regulations appropriate to utilization, including releasing the AI Operational Guidelines, supporting companies in the use of their AI, and starting discussion on AI safety regulations in the international arena. AI continues to develop rapidly, so we must make efforts to complement that with appropriate AI policies.

Prof. Ojokoh recommended that STS *forum* is well placed to support sustainability principles, and that international collaboration will be necessary for implementing AI responsibly. Bridging the digital divide will also require investments in digital infrastructure in places and countries that are lagging behind others, in order to create a balance between society.

Mr. Bess added three recommendations. Firstly, it will be important to train people in the use of AI. Secondly, investments in AI will be needed. Thirdly, not all AI is the same, so people must be tireless in research into AI to choose the most appropriate platform.

Prof. Schill added the need to support and finance projects that address understanding how AI systems work, and this must be done with an international approach.

Prof. Petit commented that it will also be essential to consider democracy. The big danger of AI is economically, such as paying to introduce AI and reduce disinformation. We must

reduce the risk of AI on different subgroups in society so as to benefit as many people as possible without influencing them. We also need to collectively promote AI modernization and make an effort in the field of education for different levels of society.

Dr. Delmolino added to the subject of human judgement and decision making, stating more important than how powerful AI models are is whether humans can trust the output. He added that, when using AI, there may be a need to identify where the AI is sourcing information from, as humans would do.

Lastly, Mr. Matsuo briefly introduced Expo 2025 Osaka, Kansai, Japan. The theme of Expo 2025 Osaka, Kansai, Japan is “Designing Future Society for Our Lives,” and it will serve as a living laboratory where people can experience the possibilities of AI.

Closing Remarks

Prof. Itoh thanked the speakers for their insights. He then commented that no one person can keep up with developments in AI, and society needs to mobilize many different players and work together to broaden the horizon on AI. At the same time, we must mobilize students to teach people how to use AI, as they are the best suited for keeping up with the leading developments in AI. Society must understand and develop healthy advancements in AI.

Basic Science, Innovation and Policy

[Chair]

Kabat, Pavel, Secretary-General, International Human Frontier Science Program Organization (HFSPO); former Director General & CEO, International Institute for Applied Systems Analysis (IIASA)

[Speakers]

Abe, Toshiko, Minister, Ministry of Education, Culture, Sports, Science and Technology, Japan

Hunt, Tim, Emeritus Group Leader, The Francis Crick Institute, U.K. [Nobel Laureate 2001 (Physiology or Medicine)]

Friend, Cynthia, President, The Kavli Foundation, U.S.A.

Becker, Katja, President, German Research Foundation (DFG), Germany

Fujii, Teruo, President, The University of Tokyo, Japan

Opening Remarks

Prof. Pavel Kabat opened the plenary session focusing on the interfaces between basic science, innovation, and policy, and invited opening remarks from each speaker.

Minister Toshiko Abe emphasized the importance of outstanding outcomes in basic science and their practical applications in creating new values and social change. She stressed the need for securing reliable and open research environments while addressing concerns about research security. Minister Abe highlighted that this fundamental principle could lead to attracting talented people from around the world, enhancing international collaboration, and producing diverse knowledge.

Kabat, Pavel

Next, Dr. Tim Hunt highlighted the unpredictable nature of scientific discoveries, citing examples such as Henri Becquerel's discovery of radioactivity and Watson and Crick's DNA structure revelation. He emphasized the importance of identifying and supporting smart young scientists, praising organizations like the European Molecular Biology Organization (EMBO) and the European Research Council (ERC) for their effective selection processes.

Dr. Hunt reminded the audience of Erwin Schrödinger's claim that "Science is a game, but a game with reality", and that the business of science is to find things out, the only way to transformative new understandings of the natural world.

Dr. Cynthia Friend then discussed the role of philanthropic organizations in supporting basic science. She noted that philanthropy is increasingly important in funding scientific research, particularly in areas where government funders have become more risk-averse. Dr. Friend emphasized the need for flexible funding and early-stage dialogue between scientists and the public to build trust and understanding. She explained that the Kavli Foundation aims to support specific areas of science worldwide in a durable and sustainable way, focusing on identifying early-stage ideas with transformative potential.

Following this, Prof. Katja Becker addressed the challenges of international cooperation in research. She stressed the importance of balancing academic freedom with national security concerns and advocated for joint development of secure international research cooperation frameworks. Case-by-case risk assessment is needed, along with trusting researchers with decisions on specific collaborations. Prof. Becker warned against overly rigid regulations that could lead to reduced innovation and called for prudent action from the international scientific community and national policymakers.

Dr. Teruo Fujii discussed the role of universities in addressing big questions of unknown challenges and new technologies. He highlighted the importance of universities becoming forums for dialogues among people from different fields. Dr. Fujii shared examples of initiatives at the University of Tokyo, including a joint summer program with Asian University for Women (AUW), and plans for a new College of Design within the University of Tokyo to nurture outstanding change-makers. He emphasized the need to create an environment where students can pursue their own interests and curiosity, potentially leading to entrepreneurial or social activities.

Discussion

Prof. Kabat opened the discussion by focusing on two aspects of basic discovery science: the human angle of who is conducting it and why, as well as the funding angle. He asked the speakers to share their views on how to attract the best minds to do bottom-up discovery science when the current system faces challenges like incentivizing frequent publications and career-building, and is therefore not conducive to high-risk approaches.

Dr. Hunt emphasized the importance of identifying smart young minds and providing them with opportunities. Dr. Hunt stressed the value of learning through mistakes and the rarity

of significant discoveries, noting that he made only about three discoveries he was proud of in his career. Progress is typically a slow and uncertain process, but by identifying people with the most potential, the chances of making great discoveries are increased.

Building on this idea, Dr. Friend highlighted three key components for supporting basic research: changing the reward system, providing flexible funding, and fostering early-stage dialogue between scientists and the public to build trust and understanding. She mentioned the Kavli Foundation's program on Ethics, Science, and the Public as an example of this approach.

Next, from the perspective of a funder, Prof. Becker emphasized the need for national and international career funding chains, recognizing PhD candidates as professionals on the beginning of their scientific journey, rather than students at the end of their education path. In addition, it is vital to establish alternative career paths for scientists who may not stay within academia and become professors. She noted that the German Research Foundation (DFG) recently published recommendations on supporting early career researchers.

When asked about balancing priorities between shorter-term wins and basic science research, Dr. Fujii stressed the importance of creating a versatile and flexible environment that allows students to pursue their own interests from an early stage, potentially leading to diverse career paths in science, business, entrepreneurial, or social sectors. He highlighted the need to make PhD programs attractive by offering diverse career options following graduation. If students have their future possibilities narrowed down, this can make them fearful of going deep into a single field of study.

The discussion then shifted to funding landscapes. Prof. Kabat asked if there was a lack of money in science innovation globally or if it was a matter of using existing funds more smartly and more efficiently.

Dr. Fujii began by answering that universities need their own capacity to provide early support for scientists, and they must work hard by fundraising and pursuing collaborations

with industry. Dr. Hunt commented on the importance of universities providing nurturing environments for young scientists.

Dr. Friend noted the increasing pressure on government funding and the growing role of philanthropy and industry in supporting basic research. She warned of a potential future shortfall in funding for basic research, especially for large-scale projects that come with large costs.

Prof. Kabat invited Minister Abe to comment on how Japan is supporting its best minds in science and covering the element of discovery science, given Japan's position as a leading nation in science.

Minister Abe responded that Japan recognizes the need for international research for this. She explained that in recent years, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been pushing for multilayered international cooperation, including international circulation of talent. This is being implemented through joint research in cutting-edge science and technology fields. Minister Abe also mentioned that MEXT is working on strengthening collaboration with ASEAN countries, promoting innovation creation, facilitating human exchange of researchers, and supporting innovative initiatives aimed at achieving the Sustainable Development Goals (SDGs).

Prof. Kabat then raised the question of whether the current highly fragmented situation in research funding was conducive to support breakthroughs in science and innovation.

Dr. Friend reiterated that gaps in funding are not keeping up with cost increases, and while philanthropy can help, industry must play a role in closing the gap. It is important to think of how to deploy funding in ways that address needs of researchers.

Prof. Becker responded that both increased funding and more efficient use of existing resources were necessary. She emphasized closer collaboration between universities, research institutions, funders, policymakers, and industry. She noted that philanthropy in Germany could be further developed compared to other countries.

When asked about the balance between competitive and core funding for basic research, Dr. Fujii suggested a combination of competitive short-term funding for new ideas and

stable long-term support for ongoing research. Prof. Becker agreed on the need for both types of funding but stressed the importance of competition for excellent research funding.

Prof. Kabat posed a hypothetical scenario about providing substantial, unconditional funding to a Nobel laureate on the basis of their reputation only. Dr. Friend and Prof. Becker both expressed reservations about such an approach, preferring to support early-career researchers or use established prize systems like the Leibniz Prize in Germany to provide funding to outstanding researchers.

On the topic of international collaboration, Prof. Becker mentioned various initiatives and organizations working to facilitate cross-border research, such as the Global Research Council and the Weave initiative in Europe. She highlighted the challenges of funding crossing national borders and advocated for open, non-thematic calls for proposals like those done by DFG.

Related to this, Dr. Hunt added that a positive aspect of the EMBO scheme is the requirement to spend time abroad, though this can be seen as troublesome by some governments.

Dr. Friend emphasized the importance of international cooperation and exchange of scientific talent as a form of soft diplomacy that enhances scientific progress and helps avoid duplication of efforts.

As a final question, Prof. Kabat invited the speakers to share their views about the most important elements in educating the next generation of scientists.

Dr. Fujii emphasized the need to support students' curiosity from an early age and provide diverse career opportunities for PhD graduates. He noted the challenges in Japan's employment system for PhD holders and suggested changes in the job market and social systems in Japan. Minister Abe commented that MEXT is comprehensively working to strengthen financial support for doctoral students and improve their employment conditions to pursue challenging research.

Dr. Hunt noted that one learns to become a scientist through pursuing projects, and this is a suitable path for young researchers. Dr. Fujii agreed on the importance of gaining both knowledge and experience through practice.

Prof. Becker echoed agreement of answers by other speakers but cautioned against putting too much pressure on students by overwhelming them with choices. She also highlighted the importance of the supervisor-student relationship.

Lastly, Dr. Friend stressed the need to teach adaptability and lifelong learning skills to prepare young scientists for a rapidly changing world.

Science and Technology for Business

[Chair]

Johnson, Ray O., Operating Partner, Bessemer Venture Partners; Former Senior Vice President and Chief Technology Officer, Lockheed Martin Corporation, U.S.A.

[Speakers]

Matsuo, Yutaka, Professor, Graduate School of Engineering, The University of Tokyo, Japan
Ha, Chu Thi Thanh, Chairwoman, FPT Software, Vietnam
Davies, Mitch, President, National Research Council Canada (NRC), Canada
Kristoffersen, Helle, Member of the Executive Committee, President Asia, TotalEnergies, France
Screven, Edward, Chief Corporate Architect, Oracle Corporation, U.S.A.
Shimada, Taro, Representative Director; Corporate Officer, President and Chief Executive Officer, Toshiba Corporation, Japan

Opening Remarks

The session was opened by Dr. Ray O. Johnson, who highlighted that today, technology is defining business. Society has undergone a number of revolutions, and now the AI revolution will cause further dramatic changes to business including the nature of work. Dr. Johnson then introduced the topics for discussion, and invited each of the speakers to present their opening remarks.


Johnson, Ray O.

Prof. Yutaka Matsuo explained that his laboratory is highly engaged in industry and academia collaboration, relying heavily on joint research. On the subject of how AI can serve industry, a growing number of businesses will be making use of generative AI, including emerging startups. AI can enhance safety and quality in various fields, including healthcare and elder care. In Japan, where the population is shrinking, improving productivity will be essential in addressing society challenges. As science and technology become increasingly specialized, AI can facilitate collaboration across isolated disciplines, which will be

crucial for tackling societal issues such as climate change. Ensuring that science and technology are used responsibly is vital, and participating in discussions such as STS *forum* will be an important responsibility.

Ms. Chu Thi Thanh Ha introduced the situation in Vietnam. Vietnam has a large number of universities and young people learning about ICT technology. She also introduced her company, FPT Software, which provides software services to customers in different areas. FPT also established a university to teach students about ICT technologies. In recent years, FPT has invested heavily in AI, nurturing AI talent in Vietnam and competing with leading AI to supply competitive visions for manufacturing and retail industries.

Mr. Mitch Davies introduced the efforts of the National Research Council Canada (NRC), which participates in many forums based on research. He added that there have been changes in the developments in society, and there is a need to accelerate the design of plants that are more resilient to climate change. AI and quantum technologies will be key to these developments, as they will change the way science and discoveries are done.

Ms. Helle Kristoffersen introduced the efforts of TotalEnergies, which has been established as an oil and gas company, and has moved more recently into power related businesses. Its ambition is to be a major player in the Energy Transition, including in the solar and wind markets. Renewables will be essential in addressing climate change, but the world's energy infrastructure cannot be changed overnight. Building a complete new energy system

will take time and require contributions from science and technology, together with societal changes. Innovation from businesses and partnerships, are equally key for science & technology, and for the energy transition.

Mr. Edward Screven agreed that science and technology have been a central part of economic growth, starting with the industrial revolution. As we move to store and manage data, the volume of data needed is enormous, not just to create economic efficiency, but for economic parity. With the rise in threats from forces seeking economic gain, it is fair to say that most companies and governments are not capable of building systems to process data in a way that is secure. The important thing is to understand how you can use that cloud technology to solve the hard problems and become more efficient.

Lastly, Mr. Taro Shimada explained the history of Toshiba, and its support of STS *forum*. The speed of progress on digital technologies, including AI and quantum technologies, has become so rapid that the adoption has become a challenge. It is important for businesses to not only architect their products in a way that provides revenue, but create products that can be smoothly upgraded with new technology. Companies must be able to adapt to new AI technologies, including future updates, otherwise they will lose their competitive edge. Furthermore, AI will require vast amounts of data, so the storage and preservation of data will be essential. Mr. Shimada also emphasized the importance of green energy.

Q&A

Following the opening remarks, Dr. Johnson asked what businesses think about managing the difficult cycles of hardware keeping up with software, and how to manage risks, including with new AI systems.

Mr. Shimada responded first, stating that having a separate software and hardware process from the design phase will create a platform that is easier to update with new technology. There is no easy solution, but companies need to be careful during the design phase of their products.

Mr. Screven also answered that there are currently many new AI models, and those will eventually settle down into more traditional software. Technology providers are focused on realizing the connection between services and hardware.

Ms. Ha also responded that FPT provides software services to clients and works closely with customers to shorten service time and make them more efficient.

Prof. Matsuo emphasized the importance of collaboration with startups. Investing in startups could provide a solution for balancing product cycles.

Dr. Johnson asked Prof. Matsuo for his opinion of how the workplace culture in Japan will change with the introduction of new technologies.

Prof. Matsuo responded that the adoption of new technologies will make organizations more flexible, encouraging greater mobility of people between companies and new lifestyles. However, many Japanese people are reluctant to switch between companies.

Mr. Shimada added that shortening the life cycle of products and technology would actually push Japanese society to become more flexible, but it is often a case-by-case situation, as it depends on the company and the business model.

Dr. Johnson then asked Ms. Kristoffersen how TotalEnergies intends to achieve a balance between decarbonization and growth in fossil energy. He also asked her to comment on the roles of government and private industry, and how to handle energy needs in the AI revolution.

Ms. Kristoffersen responded that TotalEnergies' strategy is to satisfy today's energy needs

while accelerating the build out of a lower carbon energy system. Governments also have a role to play, particularly via regulation and support of new markets ("carrot and stick"). It is important for larger companies to lead by example and to take risks.

Mr. Davies responded to the question on energy needs of AI, stating that the capabilities NCR has developed can be applied to data centers, particularly with photovoltaic technology, which can supply power to meet the needs of AI.

Mr. Shimada also added that even though AI needs energy, that energy should be green. Companies and governments must invest in green energy. Furthermore, energy usage has to be made more efficient.

Ms. Ha commented that AI can have many energy saving solutions, and may even provide solutions for more efficient energy usage.

Ms. Kristoffersen added that while some wealthier countries now worry about energy consumption for AI, there are still billions of people in the world without proper access to energy. Addressing their energy needs will be key for an inclusive energy transition.

A question was taken from the audience that asked the panelists how companies can address data cleaning and curation to ensure data used for AI is reliable.

Mr. Shimada responded that in science and technology, data is stable, but human-based data is more uncertain and opinion based. It is not possible to get consistent information, but you can record information about individuals. Data recovery mechanisms will also be needed to address the deletion of information.

Mr. Screven also answered that companies are building large language models (LLMs) and making sure those models are trained on accurate information. AI will speed up the process of innovation, so the better the tools used for AI, the better quality the ultimate products will be. Therefore, the LLMs will be updated more rapidly to keep up with social changes.

Dr. Johnson commented that there will always be bias and data bias will also need to be addressed.

Finally, Dr. Johnson asked the panelists whether they believed nuclear energy and hydrogen should be a part of the energy mix, and whether society is putting enough resources into developing the related technologies.

Mr. Shimada responded that nuclear energy should be part of the energy strategy, but it will be difficult to introduce in Japan due to social acceptance. Hydrogen is safer, but technologies still need to be developed.

Mr. Screven supported the use of nuclear and hydrogen energy, and added that more efforts need to be made to introduce them to the energy schemes. Ms. Kristoffersen and Mr. Davies also supported this view.

Ms. Ha also supported that introduction of nuclear and hydrogen energies, emphasizing the need for them to be safe.

Prof. Matsuo stated that, as a scientist, he supports the effectiveness and clean nature of nuclear energy but acknowledged that there is negative sentiment towards its introduction in Japan due to the Fukushima disaster.

AI Ethics and Regulation

[Chair]

Mital, Amit, CEO, Kernel Labs; Former Senior Director for Cybersecurity and Emerging Tech, National Security Council, The White House, U.S.A.

[Speakers]

Ammanath, Beena, Global Head of Deloitte AI Institute, Book Author of "Trustworthy AI", U.S.A.

Heikkilä, Juha, Adviser for Artificial Intelligence, European Artificial Intelligencel Office, European Commission, EU

Kitano, Hiroaki, Executive Deputy President and CTO, Sony Group Corporation; Professor, Open Systems Science Unit, Okinawa Institute of Science and Technology Graduate School, Japan

Mundie, Craig, President, Mundie & Associates., U.S.A.

Opening Remarks

Mr. Amit Mital opened the session by reflecting on the transformative potential of AI and its applications in addressing chronic diseases, mitigating climate change, and enhancing job productivity. The challenge lies in balancing this potential with ensuring AI solutions comply with existing laws, regulations, ethics, and societal norms. The evolution of AI adoption from 2022 to 2024 has highlighted the non-deterministic nature of AI-based solutions, complicating compliance and alignment with established rules. Mr. Mital proposed six key properties for a solution to unlock AI's promise, including automation of verification processes, handling rules at all jurisdictional levels and across various sectors, provision of an audit trail for compliance violations and remediation, capacity to deal with disharmonious regulatory landscapes, decoupling rules and laws from AI models for efficiency, and transparency in algorithms and data in ways such as open sourcing.

Mital, Amit

Next, Ms. Beena Ammanath focused on the importance of making AI trustworthy, outlining six dimensions of trust: fairness and bias, transparency, security, reliability, responsibility, and ethical considerations. It is essential to

consider how AI models are being trained, and the biases this can introduce. Ms. Ammanath stressed the need for technologists and scientists to take responsibility for the powerful technologies they develop, considering their wider societal impact and sustainability implications.

Dr. Juha Heikkilä presented the approach of the European Union (EU) to AI regulation, centering on trustworthy AI and the AI Act. The EU's strategy extends beyond regulation to include significant investment in research and development (R&D), and deployment of AI technologies. The risk-based approach to AI regulation only intervenes when necessary in certain uses. Dr. Heikkilä explained that the EU aims to create legal certainty across its 27 member states and actively engages in international cooperation to promote responsible AI stewardship globally. He then highlighted the EU's efforts in boosting supercomputing capacity for AI development and facilitating access to such capacity, underscoring the multifaceted nature of their AI strategy.

From the perspective of industry, Dr. Hiroaki Kitano emphasized that society is yet in the early stages of an AI-driven industrial revolution. He highlighted three stages of AI impact:

productivity, creativity, and scientific discovery, with the third potentially being the most transformative and a matter of national security. Dr. Kitano explained that Sony focuses on creating AI that enhance creativity and respect creators' rights. The company is collaborating with partners like the Singaporean government to improve representation of underrepresented languages, such as Tamil and Southeast Asian languages, in AI systems. Ethical standards and safeguards against misuse of AI and bad actors are vital elements of the company's approach.

Mr. Craig Mundie brought attention to challenges on a longer time scale, emphasizing the need for global harmonization in AI governance, especially where trust mechanisms must operate across different jurisdictions and value systems. The dual-use nature of AI technologies, with their potential for great use or misuse, requires learning from past experiences in managing other revolutionary technologies, such as those from the Cold War era. A coalition of countries and companies should be created to establish common methods of trust and develop non-proliferation strategies for AI. Mr. Mundie stressed the importance of real-time adjudication systems for AI uses to solve dual-use problems across jurisdictions. He also highlighted the need to consider AI governance in the context of critical infrastructure and layered trust systems.

Discussion

Mr. Mital began the discussion by asking about current best practices for managing AI risks.

Ms. Ammanath emphasized that the biggest risk is not using AI at all. She then outlined three key practices. First, ensuring basic AI literacy for everyone, which needs regular updating due to constant advances. Second, incorporating ethical AI checks into project management tools, prompting teams to consider potential risks and side effects. Third,

viewing AI ethics and compliance as an ongoing process throughout the lifecycle of an AI product or solution, not as a one-time consideration.

Next, the chair raised the question of how AI efforts to harmonize compliance approaches can be effective beyond its borders.

Dr. Heikkilä explained that the EU actively engages internationally, working with partners to develop compatible approaches. He cited the G7 process as an example, where Guiding Principles and a Code of Conduct for Developers of Advanced AI Systems were developed during the Japanese G7 Presidency. The EU aims to ensure international agreements align with their framework, while recognizing that concrete solutions may differ between jurisdictions. Dr. Heikkilä added that the EU's work includes multilateral processes as well as bilateral relationships with partner countries to advance approaches.

Following this, Mr. Mital asked how a global company such as Sony views an effective approach to apply policies and regulation to AI products deployed worldwide. Dr. Kitano described three key pillars. One, staying connected through active involvement in AI ethics discussions and committees. Two, internal governance, such as committees with the power to veto products that do not meet guidelines. Three, substantial R&D efforts to support

businesses in developing compliant AI products and services quickly.

Mr. Mital then asked about the risks of an unbalanced global regulatory environment. Mr. Mundie warned of the risk of Balkanization, where if different regions produce localized regulations that seem aligned in principle but differ in practice, it could lead to significant challenges for global companies and consumer confusion about what can be trusted.

Q&A Session

A member of the audience asked about the potential delay in AI application development due to regulations being implemented at different times across countries.

Dr. Heikkilä responded that the EU has not asked innovators to wait, but has instead built a mechanism whereby the provisions of the AI Act become applicable in stages over 6 to 36 months. This approach aims to enable innovation while giving providers time to adapt.

Ms. Ammanath added that regulations will likely be industry-specific and use-case-specific, rather than a single set of rules for all AI. She noted that highly regulated industries are already adapting existing regulations, while newer industries may require more time to develop robust regulations.

Dr. Kitano stressed the importance of sustainable success and respecting creators' interests and rights when deploying powerful AI tools in areas such as music and art. Creators must be recognized for their work and proper rules should come into place for permission and compensation.

Mr. Mundie added that from a software business perspective, oversight mechanisms need to evolve with uses, as it is impossible to anticipate all ways AI will be deployed. He emphasized that while risks must be balanced with the utility and empowerment the tools can provide, the biggest mistake would be not to use AI at all.

Next, another member of the audience asked about the concept of trust with AI and how it compares to how trust is viewed within human society.

Mr. Mital explained that AI systems should be governed by human rules and ethics, with transparency in both data and algorithms being crucial for building trust.

Dr. Kitano pointed out that trust in AI is essentially trust in the operators and service providers of AI-based products and services.

Ms. Ammanath highlighted the generational aspect of trust, noting that definitions may evolve with digital natives.

Offering another view, Mr. Mundie described trust in AI systems as a layered problem, emphasizing that holding only the AI platform operators or those who create large language models accountable is insufficient, as applications built on top of these platforms also play a crucial role in trustworthiness.

Dr. Heikkilä outlined the EU's approach to general-purpose AI models, which focuses on transparency by requiring information and documentation to be provided to downstream developers to enable them to comply with the AI Act.

Ms. Ammanath agreed with the need for constraints and suggested that those building powerful tools should pause to consider the broader implications of AI deployment.

Closing Remarks

Mr. Mital highlighted the panel's optimism about AI's transformative potential while acknowledging the need to protect disadvantaged groups from AI's misuse. He noted that key discussion points included AI's global impact on trade, its implications for national security and sovereignty, and the importance of transparent datasets and algorithms. He also emphasized the challenge of balancing regulation with innovation and concluded by acknowledging the complexity of the topic.

Global Health

[Chair]

Walport, Mark, Foreign Secretary, The Royal Society, U.K.

[Speakers]

Abdool Karim, Quarraisha, President, The World Academy of Sciences (TWAS), South Africa

Dagvadorj, Amarjargal, Member, Relief and Development Department - Mongolia, Global Young Academy; Head of Programmes, Relief and Development Department, People in Need Mongolia, Mongolia

Demartines, Nicolas, CEO, University Hospital CHUV, Switzerland

Larson, Heidi, Professor of Anthropology, Risk and Decision Science, Infectious Disease Epidemiology and Dynamics, London School of Hygiene and Tropical Medicine, U.K.

Samuel, Didier, Chairman and Chief Executive Officer, French National Institute of Health & Medical Research (INSERM), France

Opening Remarks

Sir Mark Walport opened the session by pointing out that the widespread availability of clean water and vaccines, combined with good nutrition, has enabled people to live for longer. Nevertheless, there are still challenges, such as huge inequalities between and within countries. Furthermore, as people live longer, they have more health challenges. There are also demographic issues affecting public health, such as aging societies and the environment. In addition, many health systems remain disease systems, with more effort devoted to treating people who are ill than to helping them maintain good health. There are also many factors affecting lifelong health outside medicine, such as education, transport, housing, work, and economics.

Walport, Mark

Prof. Quarraisha Abdool Karim stated that infectious diseases and epidemics offer a sobering reminder of the inequalities that exist between the Global North and Global South and that as long as there are infectious diseases, no one is safe until everyone is safe. She also noted that wars erode socio-economic stability, which exacerbates the ability

of countries to deal with health crises and also creates conditions that enable pathogens to mutate and new variants to emerge as evidenced by the Mpox outbreak in the Democratic Republic of Congo. On the positive side, the combined efforts of the private sector, activists, scientists, and all United Nations member states enabled antiretroviral treatment to be available and affordable to everyone everywhere, changing the face of AIDS from an inevitably fatal one to a chronic, manageable condition. This is a great example of global solidarity and highlights how when we work together with unity of purpose we can achieve great things. When thinking about global health, addressing inequalities should not be viewed as acts of charity, but as important efforts to meet basic human rights so that everyone can thrive.

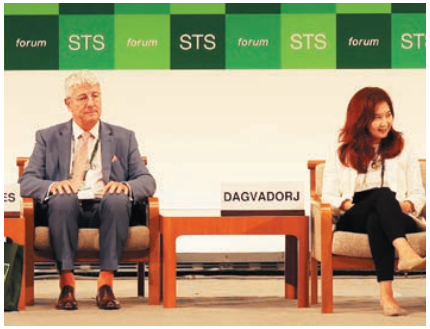
Dr. Amarjargal Dagvadorj pointed out that global health is closely tied to climate change and air pollution, while noting that although Mongolia faces some of the strongest impacts of climate change, it is one of the smaller contributors to it. Notably, Mongolia's average temperature has risen by 2.1°C over the past 70 years, which is twice as fast as the global average. Climate change is making the global population susceptible to outbreaks like COVID-19 and other diseases. The world also faces major air pollution problems, with only seven countries reaching the international air quality standards. Air pollution makes people

more susceptible to many diseases and exacerbates the danger of various chronic diseases. Disturbingly, air pollution claims the lives of seven million people worldwide annually. One promising development is the World Health Assembly's recent agreement to revise the World Health Organization International Health Regulations in recognition of the importance of the interconnectedness of the world.

Prof. Nicolas Demartines spoke about three challenges, from a technical point of view, in medicine. The first is managing and controlling huge advances in technology, such as robotics, imaging, and AI. The second is balancing these technological advances with soft skills or the human factor, entailing holistic care as part of a multidisciplinary strategy. The third is to generate outputs from medical progress and make it accessible to low and middle-income countries. Technology can contribute to democratizing healthcare, for example through telemedicine, which could reduce healthcare inequity. Technological developments will increase the quality of care that can be provided to patients, but there is a need to maintain and improve complementary soft skills. These developments also need to be funded. Investing in these and all aspects of healthcare can reduce its long-term cost.

Prof. Heidi Larson talked about the global state of vaccine confidence. There is no more globally relevant health intervention than vaccines. However, the public health community has taken the public's acceptance of vaccines for granted. The development of mRNA technology, for example, is proceeding at a pace that is faster than the public is prepared for. In fact, issues were emerging from even before the COVID-19 pandemic, when such technology gained prominence. The Vaccine Confidence Project was founded in 2010 to aid better understanding of vaccine confidence or skepticism in the world. Vaccines face a number of issues that are also evident in other areas of science. There is a need to engage the public and help it to try to catch up with the pace of scientific innovation, and the Vaccine Confidence Project seeks to do that. The underlying issues of trust related to vaccines must be urgently addressed and apply to many other domains, including trust in policies, institutions, scientists, and governments.

Prof. Didier Samuel highlighted the importance of accounting for globalization and global interconnectedness in combating



emerging infectious diseases. Many such diseases are zoonoses and their rise has been exacerbated by the interconnected nature of the world and poor access to vaccines in some regions. It is important to focus on researching and combating these emerging infectious diseases, while, at the same time, refocusing efforts on non-communicable diseases. Climate change is also an important factor that will change society, modify the cell biology of humans, and impact the migration of populations and emergence of new diseases. Medicine is often seen as being about disease therapeutics, but disease prevention must also not be neglected. Lastly, it is vital to take a global view of research, taking into account changing environments, the changing climate, and changing diseases.

Discussion

Sir Mark opened the discussion among the panelists and noted that during the COVID-19 pandemic, countries naturally stockpiled vaccines as the first priority of governments is to look after their own country. Prof. Karim agreed but pointed out that rich countries not only stockpiled vaccines but stockpiled far more than they needed. Another issue was that many low and middle-income countries participated in clinical trials, yet the benefits were not fully shared with them. In addition, there was a need for a mechanism for advanced purchasing, but this put low and middle-income countries at the end of the queue.

Sir Mark asked whether distributed manufacturing or some other solution could prevent history from repeating itself during the next pandemic. Prof. Karim noted that there was indeed a lot of discussion about decentralized manufacturing and building capacity during the pandemic. It was also promising that a Pandemic Treaty was developed, but unfortunately it was not signed.

Sir Mark noted that in the case of Mpox, the obvious solution is to saturate the region with smallpox vaccines. He wondered if sufficient amounts are being made available. Prof. Karim did not think so. She also pointed out that delayed responses have led to a failure to contain the outbreak. This suggests a complacency as a global community when dealing with infectious diseases in lower-income countries.

Sir Mark asked Prof. Larson what was insufficient about the communication around the COVID-19 vaccine, noting rising vaccine skepticism in the world. Prof. Larson replied that there was no communication until the first vaccine was developed, and the communication was initiated by the companies, not the public health authorities. There was insufficient transparency, which is a key aspect of trust and which a recent study showed was the foremost thing the public expects from government.

Sir Mark turned to the prevalence of hepatic cancer in the world. Dr. Dagvadorj pointed out that Mongolia has the world's highest incidence of hepatocellular carcinoma, which is in part due to a lack of vaccines against the hepatitis B virus (HBV). Sir Mark asked how prevalent smoking was there. Dr. Dagvadorj revealed a concerning statistic that 50% of the male population smokes, and 80% of smokers do so inside the home. There is an urgent need for a social awareness campaign that smoking endangers not only the smoker's health, but also the smoker's family members, who face a significantly higher risk of developing liver and other digestive system cancers.

Sir Mark asked how hepatic cancer could be tackled. Prof. Samuel stressed the importance of neonatal anti-HBV vaccinations, which prevent maternal to child transmission and break the path of the epidemic. HBV is even more highly transmissible than the human

immunodeficiency virus, so it is extremely important to ensure access to its vaccine. This requires communication but also political organization. Sir Mark noted the similarity with cervical cancer, which can be prevented with the human papillomavirus vaccine.

Sir Mark then asked whether technological advances might in fact exacerbate inequalities between the rich and poor, rather than democratizing health care. Prof. Demartines acknowledged the possibility and suggested that education is needed to instill the correct knowledge and popularize and democratize the correct application of new technologies.

Sir Mark also raised the importance of political determinants of disease. Prof. Karim agreed on the value of having the right policies and programs, as well as political commitment.

Q&A

A question-and-answer session was then held with the audience. A participant noted that a recent paper, based on better data and changed metrics, stated that previous estimates and measurements of access to clean water and sanitation was off by 100%. He also noted that the presence of diseases can be tracked by monitoring wastewater. Prof. Karim agreed that enhanced measurement with good indicators is key to successful actions. She also cited a study showing that screening wastewater in 12 airports in the world present a good picture of which viruses are circulating globally. Prof. Demartines added that antibiotics, radioactivity, and chemotherapy agents can also be monitored in wastewater. Prof. Larson pointed out the need to factor in changes to the world such as climate change and mass migration from wars and conflicts.

The next question concerned the development of vaccines on the African continent. Prof. Karim supported their development in Africa and noted the importance of investing in research capacity and diagnostics capabilities to ensure resilient health systems. Sir Mark wondered whether the mRNA platform would become democratized. Prof. Karim believed that decades of investment would be needed to be able to develop and manufacture such technology in Africa. North-South partnership would also be important for transferring technology.

A participant then asked about the future of global health cooperation. Prof. Samuel urged that the importance of global cooperation should not be forgotten. He suggested such cooperation could be promoted at various levels, including between researchers, between scientific societies, between institutions, and between governments. Common funding

should also be set up at the international level. There should also be opportunities for governments to fund international programs. Prof. Demartines added that in an ideal world, not only governments but also industry should participate in global collaboration.

Lastly, a participant said that AI is shifting the paradigm from treatment to prevention, but a lot of healthcare systems remain oriented towards treatment. She asked what kind of push can be made to shift systems to prevention and make prevention attractive to businesses. Sir Mark agreed that public health suffers from market failure as keeping people health is not currently profitable. Prof. Karim pointed out that the younger generation seems to understand the paradigm shift and the importance of preventive health better than older generations. Dr. Dagvadorj noted that this is also connected to the issue of democratization of healthcare. She explained that Mongolia has a small population spread over a very large geographical area, so democratization of healthcare would not work well. Instead, Mongolia has adopted an alternative approach, establishing over 360 primary care units strategically located throughout its administrative regions to reach even the most isolated nomadic communities across the expansive Mongolian steppe. Achieving accessible global health requires careful consideration of these diverse factors and challenges.

Sir Mark closed by noting that one of the major opportunities is empowering the young, who are the future.

Shaping the Future of Higher Education

[Chair]

Drake, Michael V., President, University of California, U.S.A.

[Speakers]

Minato, Nagahiro, President, Kyoto University, Japan

Scherpen, Jacquelien, Rector Magnificus, University of Groningen, Netherlands

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

O'Reilly, John, former President, Khalifa University, U.A.E.

Ruktanonchai, Uracha R., Executive Director, National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA), Thailand [Future Leader 2014]

Opening Remarks

Dr. Michael V. Drake began the session by stating that the institutional priorities of the STS *forum* align with the fundamental missions of research, teaching, and public service that define today's universities. To highlight these shared goals, the plenary discussion focused on four key areas of impact—namely, the adoption of generative AI and emerging technologies, the revolution of teaching in the workforce, and the state of campus movements. He then invited the panelists to present their opening remarks, which are summarized below.

Drake, Michael V.

Dr. Nagahiro Minato presented first, highlighting the increasing social expectations placed on universities in Japan, which coincide with a decline in the economy and increasing sense of social stagnancy. Given the rapid technological advances and globalization in recent decades, it is natural that Japan's research would move to open technological innovation and the production of human resources versed in rapidly developing information technology. It is therefore important for universities

to redefine their missions and structure to meet contemporary social expectations, while maintaining their long-standing core principles of academic freedom. The formation of multidisciplinary and multi-sector platforms will help to address emerging global issues. Universities should seek to transform reliable knowledge and inventions into social values that contribute to human well-being. Fulfilling such functions should lead to more trusting and robust relationships between universities and society.

Prof. Jacquelien Scherpen introduced the concept of University 4.0., which refers to how universities must combine research, innovation, and society. The collaboration between universities and society is impacting the world. Multidisciplinary and transdisciplinary research and innovation will be essential in addressing modern research. This is also motivating young people to join universities, and provides deep insights and solutions in the long term. Universities must maintain their values in research and education to address major social challenges. Universities are promoting regional partnerships and global scientific methods of development, which will be necessary to attract the next generation of students and the workforce.

The Honorable Deborah L. Wince-Smith then stated that universities are an important part of society and social competitiveness, becoming drivers of productivity and the heart of the industry. The pandemic had a huge impact on universities, creating a time of transformation of universities into places of innovation. Communities are expecting universities to educate the next generation of scientists, but also to become the glue that holds economies and societies of the future. The bronze age civilization can be seen as a prototype to the world today, where technology and knowledge determine which societies will flourish.

Next, Prof. John O'Reilly then talked about the history and future outlook of universities. Universities today are places for disseminating existing knowledge, discovering and creating new knowledge, and fostering and enabling the exploration of knowledge to the benefit of society and economy. This is the culture and nature of major universities around the world, but it is evolving. Education is becoming more personalized, taking advantage of technological developments to provide tailored education to students, as universities used to do in the past.

Dr. Uracha R. Ruktanonchai then spoke on behalf of the National Science and Technology Development Agency (NSTDA), an autonomous agency in the government of Thailand focused on driving research and innovation, and promoting collaboration between universities and industry. NSTDA had identified a number of approaches to promote research and the future of higher education. The first is developing higher education and keeping students

involved at university to nurture young talents. The second is developing the workforce through initiatives and workforce collaborations. Technology plays an important role in universities and research, but they should be equally committed to human capacity building necessary for the sustainable growth of the workforce.

Discussion

Dr. Drake asked the first question to Dr. Ruktanonchai and the Honorable Wince-Smith, prompting them to reflect on the future of AI in education.

The Honorable Wince-Smith responded that AI is a tool, and how we master this new tool will be important for human civilization. We must have human centered understanding on the potential of AI. There has never been enough discussion on the criticality of the merger of art, social sciences, and philosophy with STEM. It is important to have STEM disciplines, but the world needs engineers that think like artists, and visa versa, or we will move away from the ultimate purpose of human existence described by Aristotle as Eudaimonia, which means to thrive.

Dr. Ruktanonchai responded that while AI and emerging technology will shape industry, it is important to also consider talent development and how to keep people motivated to be in the workforce. We must consider the ethical frameworks and technology awareness, with universities at the center to ensure effective implementation.

Dr. Minato also commented on the importance of ensuring truth, as AI technology can be affected by misinformation. He emphasized that we must develop the literacy to use AI, and it will take a long time to train AI technology to test the truth of data.

Dr. Drake then asked Prof. Scherpen for her views on the future of AI in higher education.

Prof. Scherpen responded that there will be teachers and students who will excel in using AI, and those who will not. In the long term, AI will be part of education in the future, but face-to-face interactions—without the use of AI—are still invaluable to higher learning. People

must be socially responsible because AI is only as good as the data input. Universities must also develop a system that can identify when something is true or not.

Dr. Drake asked Prof. O'Reilly about the steps for the transition in education.

Prof. O'Reilly emphasized the importance of human interactions together with introducing new technology. Personalization of education can be done with AI, but it will lack inspiration. Also, knowledge sharing, creation, and application are all part of the education experience.

Dr. Drake asked Prof. Scherpen to elaborate on the concept of University 4.0 and the potential of University 5.0.

Prof. Scherpen explained that University 1.0 focused solely on learning through lecture-based methods; 2.0 advanced research and education simultaneously; 3.0 centered on interdisciplinarity; and 4.0 represents the creation of a less insular ecosystem where industry, government, society, and academia have started to work together. University 5.0 will be defined by a stronger focus on co-creation through these emerging partnerships.

Dr. Drake then asked all the panelists to share what they are optimistic about and concerned about with regard to changes in higher education.

Dr. Ruktanonchai responded first, stating that technology can improve the efficiency of education, but ethics will be a concern. Technology implementation can help in terms of underserved populations getting into loop and providing inclusiveness.

Prof. O'Reilly stated he was optimistic about students adaptation, but concerned about the reluctance to incorporate new technologies.

The Honorable Wince-Smith then commented that universities will have to be innovative in addressing obsolete business models. She added that there is a realization that universities will thrive when they are anchored by public support, and that universities will have a key role in developing the prosperity of the local communities.

Prof. Scherpen then answered that she was concerned about the potential lack of debate. It is important to foster academic freedom and follow methods that are scientifically sound. Various perspectives will need to be heard, and there will be resilience from an older generation on change. Change often comes from young people, but it needs to be constructive.

Lastly, Dr. Minato responded that when you have problems with society, you need unbiased platforms where all stakeholders can conduct fair and evidence-based discussions. This is a potential role that universities could fulfil in tackling the broad issues faced by all people.

Q&A

A question was taken from the audience, asking about the role and responsibility of universities in entrepreneurial activities, such as startup companies.

Prof. Scherpen responded that it is important for universities to create an environment where start ups can flourish. Various systems to support start ups are already in place.

The Honorable Wince-Smith also commented that the culture of universities will be important, and that there are universities that have a record of supporting start ups. Furthermore, having institutional frameworks to ensure that the intellectual property is filed, etc., and creating institutional frameworks will be necessary. One of the challenges of start ups is how to scale the enterprises, but there are efforts to address this, including the use of AI, and

there will likely be a wave of entrepreneurship with emerging technologies out of university and also with partners in industry.

Another question from the audience invited the panelists to reflect on how universities will continue to change with the emergence of AI.

Prof. O'Reilly responded that AI is transformational, and it will achieve personalized education. It is only one of the vehicles that can be used to promote change. He also noted the importance of international experience.

Takeaways from Concurrent Sessions

[Chair]

Kleiner, Matthias, Professor, Technical University of Dortmund, Germany; Scientific Advisory Board Member, Representative, Werner Siemens Stiftung, Switzerland

[Speakers]

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

Schütte, Georg B., Secretary General, Volkswagen Foundation, Germany

Abdul Hamid, Zakri, Chairman, Malaysian Industry Government Group for High Technology (MIGHT) / ATRI Advisory, MIGHT / ATRI Advisory; former Science Advisor to the Prime Minister of Malaysia, Malaysia

Skipper, Magdalena, Editor-in-Chief, Nature, U.K.

Mazur, Eric, Balkanski Professor of Physics and Applied Physics, Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University; Past President, Optica, U.S.A.

Hassan, Mohamed Hag Ali, President, Sudanese National Academy of Sciences (SNAS), Sudan

Ohno, Hideo, Special Senior Advisor to the President, Tohoku University; Special Advisor on Science and Technology, Ministry of Economy, Trade and Industry, Japan

Adem, Alejandro, President, Natural Sciences and Engineering Research Council of Canada (NSERC), Canada

Liu, Jia, Project Associate Professor, Kavli IPMU, The University of Tokyo, Japan [Young Leader 2024]

Taylor, Stephen, Assistant Professor of Physics & Astronomy, Department of Physics & Astronomy, Vanderbilt University, U.S.A. [Young Leader 2024]

Kleiner, Matthias

Opening Remarks

Prof. Matthias Kleiner explained that during this session, speakers will report on the key takeaways from the 24 concurrent sessions across 8 thematic tracks. Young Leaders will also be invited to share their experiences from this year's meeting.

Takeaways from Concurrent Sessions

Dr. Thomas Mason presented the takeaways from the energy track. The session on *Action for Net-Zero Emission* began with participants noting that the impacts of climate change have already begun and the world is behind the curve in the need for action. There are already some technologies ready for deployment and the near-term needs are clear. However, many technologies do not have adequate maturity to reach the necessary scale. In the longer term, technologies for the removal of CO_2 from the atmosphere will also be needed. The participants also discussed how means of energy distribution need to factor in equity and accessibility. Efforts around the world to deploy net-zero options were also shared. In addition, the role of oceans was also discussed.

In the session on *Investment and Financing for Energy Transition*, participants noted that current global investment in energy transition is less than a quarter of what is needed. The example of Japan was considered, where concerns around decarbonization and clean energy are linked to elements of economy and trade, and there are multiple factors driving the need for an energy transition. The role of private investors was also taken up. Participants also discussed the importance of carbon capture and storage. In addition, they noted that the financial sector alone is insufficient to fund the energy transition. While participants recognized the importance of energy efficiency, they also noted there will continue to be a demand for more energy.

The third session was on *Solutions to Renewable Energy Intermittence*. The participants considered three categories of challenges, namely the short-term fluctuations in the grid, daily variations, and balancing across seasonal timeframes, and discussed potential solutions for managing them.

Dr. Georg B. Schütte presented takeaways from the Earth and commons track. The sessions were, in order, *Digital Twins of Ocean, Food and Water Security, and Circular Economy toward End of Mining*. There are high expectations for science and technology systems to provide solutions to issues related to the global commons, and all three sessions addressed nexus challenges. The first session addressed the nexus of oceans and climate change, and the role of oceans in absorbing heat. Participants dealt with issues such as the warming of oceans at different rates in different regions and the exacerbation of diseases by the warming of oceans. They noted how digital twins might enable better understanding of the fluctuation of oceans and new solutions. However, challenges include getting enough data, getting the right data, and ensuring the data are sufficient to produce the right digital twins. There is also a need to bridge local and global knowledge, engage local and global stakeholders, and leverage indigenous knowledge.

The second session dealt with the nexus between water, climate, and soil, which is complicated by conflict. The world runs the risk of reaching peak soil and peak water in 2050. In the short term, there needs to be humanitarian relief, in the medium term, a change in the trajectory of water and soil use, and in the long term, transformation of the food production system. Science and technology can offer some solutions, but these must be supported by other efforts such as the right regulatory incentives.

The third session dealt with the nexus between material supply and energy. Examples were shared from different countries on improving the recycling of materials and developing circular economies. The concept of circular engineering was also discussed. The participants considered short-term concerns around recycling issues, mid-term concerns concerning pricing externalities, and the long-term perspective of needing science and technology breakthroughs. Such breakthroughs are needed in the improvement of circular engineering and the design of new materials that are more resource efficient and effective.

Prof. Zakri Abdul Hamid summarized the discussions from the climate risks and demography concurrent sessions. In the *Adaptation to Climate Change* session, participants noted that the issue of adaptation has been overshadowed by mitigation, and that mitigation and adaptation must be discussed together. There is also a greater need for support for local and regional levels to implement controls. The Biosphere

2 controlled environment project to study the impacts of climate change was also examined. In addition, participants discussed the hydrological cycle and rainfall. Another topic was ways to ensure that mitigation, adaptation, and transformation drive climate resilience, including financing systems. Adaptation inclusion, the role of traditional knowledge, the need for balance, and demographics and economic considerations were taken up as four central themes of climate risks.

The session on *Declining Population* examined population decline through history and its link to population aging. Participants also considered the case of Africa, where the fertility rate is double the rest of the world, and how this affects societies and governments. Furthermore, they looked at Singapore, which is attempting to build strong and cohesive societies while preserving the multicultural nature of society, supporting a dynamic and vibrant economy, and providing high quality living environments for all. In addition, participants noted the importance of measures to incentivize fertility, such as creating child sensitive demographics.

Dr. Magdalena Skipper shared the takeaways from the concurrent sessions on life sciences, which she suggested might be better classified as the biomedical science track. Before providing her report, she congratulated Victor Ambros and Gary Ruvkun for winning the 2024 Nobel Prize in Physiology or Medicine, noting that their work on microRNA and its role in post-transcriptional gene regulation was an excellent example of basic research, the importance of which was emphasized across all sessions in the life sciences track.

In the *Breakthrough in Biotechnology* session, participants talked about various breakthroughs, such as efforts to build molecular atlases of different cell types, accelerated by advances in omic technologies and computational tools. Such approaches are accelerated by open science principles. Participants also learned about novel technologies, including those that advance regenerative medicine. They also touched on how agile, flexible, and scalable manufacturing mechanisms support drug discovery and development. The potential of G protein coupled receptors as therapeutic targets and efforts to leverage this was discussed as an example. In addition, the participants noted that computational tools and AI are transforming and accelerating biotechnology research. However, they also recognized the existence of shadows such as high barriers to entry arising from the cost of accessing good data sets and energy consumption. There is no doubt that such advances in biotechnology have transformed society, improving human, animal, and plant health, but these benefits are not equally enjoyed around the world.

In the session on *AI for Health*, participants agreed on the importance of health as a field for the application of AI. They spoke about challenges, such as data availability and quality, and benefits such as allowing doctors to spend more time with patients. They agreed that the rise of AI should augment physicians, not replace them. AI should be more directed towards administrative tasks, rather than replacing human diagnostic capabilities. It is also important to make the most of the complementarity between AI capabilities and human intuition. Furthermore, care should be taken to ensure AI is not used to amplify misinformation and disinformation and ensure data privacy and security. The participants also debated whether regulation helps or hinders the collection of data and the deployment of AI. In addition, they noted the need for government-industry-academia collaboration to ensure the benefits of AI in healthcare are widely enjoyed across society.

The final session was on *Patient Advocacy*, during which participants noted the importance of patient participation in research. The involvement of patients in clinical trials for drugs can yield otherwise unobtainable insights to pharma companies. An initiative to engage and improve the health of residents of Pakistani and Bangladeshi heritage in East London was discussed as an example of community engagement. In addition, the important role of advocacy organizations was discussed, as was the need for their independence and diversity in their representation. The participants also noted the value of research efforts centered on community engagement and co-learning with residents.

Prof. Eric Mazur presented the messages from the track on innovative engineering, which involves integration of new ideas, unconventional approaches, and emergent technologies. Common threads across the sessions included leveraging technological advancement to tackle global challenges, and the importance of interdisciplinary collaboration and education. All sessions touched on the need to educate and foster the next generation of innovators. They also emphasized the role of new technologies.

The session on *Revolutionary Materials and Devices* considered how new materials have driven human development. However, there is a need to reduce CO_2 emissions from manufacturing these materials and to promote circular economies, and strategies for those purposes were discussed.

The next session was *Quantum Science and Technologies*. Quantum technology involves leveraging the properties of quantum particles, which behave in unusual ways, to develop new technologies. Participants highlighted the transformative quality of quantum computing, including accelerating materials discovery. However, an important shadow of quantum computing is its ability to break encryption methods. Participants also discussed quantum metrology, quantum communication, and quantum sensing.

In the session on *Green Technologies*, the participants noted the many exciting developments in recent years. The participants focused on barriers that limit even more rapid deployment of these technologies and agreed that social and political obstacles are the main hurdles.

A common thread across the three sessions was the need to foster a workforce with an innovative mindset. Furthermore, there is a need to acknowledge that the road to innovative engineering is littered with setbacks and failures, so innovative engineering entails embracing risk, remaining resilient to failure, and allowing serendipity to do its work.

Prof. Mohamed H. A. Hassan summarized the takeaways from the concurrent sessions on cooperation in science and technology, whose themes were interrelated and intersect with other wider themes in cooperation in science and technology, including utilizing science and technology to drive sustainable development, exploring the transformative potential of novel technologies in various sectors, and the training of the next generation of talents.

The sessions aimed to create a comprehensive approach for advancing collaboration in science and technology to meet global needs and support sustainable development.

In the session on *Science and Technology Diplomacy*, participants noted that science and technology diplomacy plays an important role in international cooperation and paves the way for countries to overcome political differences and work towards common good. National priorities can sometimes hinder cooperation, so a balanced approach that respects national priorities and the broader goal of international cooperation is required. The integration of diplomats and scientists is essential in fostering communication between governments and the global scientific community and professional science advisors play a pivotal role in translating technical knowledge into policy.

In the session on *Collaboration among Academia, Industry and Government,* the participants discussed how such collaboration is vital for addressing societal challenges, such as vaccine development and food security. Industry, governments, and scientists all have an essential role to play. Participants addressed the need for collaborations to include society to foster community support and ensure sustainable and impactful solutions. Open communication is key, and scientific literacy and education are essential for keeping the public informed. Participants also discussed strategies for fostering collaboration. They also identified challenges in public education and ways to overcome them. They proposed training scientists in education and adding scientific communication to curricula. The importance of trust and industry funding for academic research was emphasized as well.

In the session on *Nurturing Innovation-based Startups*, the participants stressed that it is essential to foster environments where new ideas can flourish and expand at scale, with start-ups and breakthrough technologies being more critical than ever. The participants concurred that technological innovation can disrupt markets and significantly impact societies, that successful innovation ecosystems often involve research-intensive institutions, that evaluation of technological enterprises varies regionally, and that access to entrepreneurial leadership and a skilled workforce is crucial for growth and success.

Prof. Hideo Ohno recapped the discussions from the concurrent sessions on science and technology education. In the session on *Fostering New Generations of Scientists with Inclusion and Diversity*, participants noted the crucial role of science and technology in tackling global challenges and that the quality of these efforts depends on the selection of the best talent, regardless of background or cultural factors, to ensure a richness of backgrounds and plurality of perspectives. There is in particular a need to ensure greater participation of women in science, technology, engineering, and mathematics (STEM) fields and participants talked about efforts to promote this in India. The participants also stressed the importance of inspiring an affinity for science from a young age, particularly among girls. Other topics discussed included the influence that family members, schoolteachers, and peers can have on women and minorities at a young age regarding science and the inherent bias of AI regarding diversity and inclusion.

The participants in the *AI in Education* session discussed AI's potential for integration and disruption on higher education. AI can scale learning and research more effectively, which could render universities in their current form obsolete. The importance of integrating AI in lifelong education to meet the needs of aging was also stressed. Participants also considered the idea of AI-enabled precision education, including use of AI to enhance young people's motivation towards science education. However, AI could also be used to direct young people's motivation elsewhere, raising ethical issues and highlighting the role of the social sciences and humanities. Participants agreed that AI in education should ultimately be aimed at enhancing human capabilities, rather than replacing them, and that humanity must remain at the core of education.

The final session in the track was *Signaling the Trustworthiness of Science*. The participants agreed that maintaining public trust in science and technology is hugely important. Science and its insights can change with new discoveries, which is a point not fully understood by the public. There have been several incidents showing the critical nature of public understanding and the challenges of maintaining credibility in science, such as during the Great East Japan Earthquake, when the public's trust was shaken due to initial limited information being released on the impacts of the Fukushima nuclear disaster, and during the COVID-19 pandemic, when the public was confused by conflicting information. Predatory publishing also affects science's credibility and trustworthiness. Finally, it is essential to protect academic freedom and maintain universities as independent entities.

While the first session showed the challenge of changing environments and mindsets, the following two sessions showed how rapidly the science and technology environment are evolving. All sessions demonstrated how science and technology are intertwined with society and how they must work with society for a better future.

Dr. Alejandro Adem summarized the takeaways from the digital technologies track. Technology is evolving at a faster pace than ever imagined. This raises many challenges such as cyberattacks and data security that require urgent and coordinated action. In the first session, on *Countering Disinformation in Digital Age*, the participants pointed out how the spread of disinformation is now faster, easier, and more dangerous. Fact-checking alone is insufficient. A systems-based approach is needed. Furthermore, efforts to combat disinformation must not only be online but also offline. AI approaches to combating it are being developed but broader efforts are needed, including intergovernmental coordination and public education. Above all, public trust is essential to counter disinformation. At the same time, there is a need to balance security with privacy.

In the session on *Cybersecurity*, participants highlighted the need for urgent action to address the constant threat of cyberattacks. The energy sector in particular is critically vulnerable. However, many of these vulnerabilities could be addressed by basic cyber

hygiene, such as multi-factor authentication. However, human behavior continues to be a weak link in cybersecurity. Such human behavior needs to be tackled, alongside producing technological solutions. Another challenge is that AI is changing the landscape of cybersecurity and making it harder for people and nations to keep up with cyber criminals.

In the session on *Sensor Technologies*, participants noted how such technologies are critical to AI. Quantum sensing in particular unlocks new potential for scientific discovery. Sensors are everywhere collecting vast amounts of data, and as these data are integrated in AI, AI will be able to make ever more powerful predictions. However, data security and privacy are critical concerns. We must ensure data is used in ethical ways. We must also be aware that sensors can misinterpret information and that such errors could be critical in some sectors.

Report by the Young Leaders

Dr. Jia Liu shared her experience attending this year's meeting. STS *forum* provided her with a great opportunity to learn about the dialogues and debates occurring in other fields. During the quantum computing session, Dr. Liu learned about efforts to apply quantum computing in commercial test cases and was amazed by the level of this technology's capability. She also attended the session on green technologies, learning that while many of these technologies are available, many have not yet been adequately deployed, with challenges including regulation and public acceptance. Dr. Liu believed that STS *forum* is a good example of interplay between science and technology and society. For her, the most interesting experience was the human factor and being able to network with other participants and be mentored by more senior participants.

Dr. Stephen Taylor explained that he often participates in very specialized conferences and suggested that the strength of STS *forum* is that it gathers so many participants at a high level that can enact real change to tackle the biggest issues affecting society. He noted that AI has been an overarching theme at the meeting. AI seems as powerful as nuclear power in terms of its ability to transform society, but also its potential destructiveness. Another theme was broader participation in STEM education and approaches to overcome this. Yet another

important theme was rebuilding trust with the public through communication and education to foster greater scientific literacy.

AI Summary
Following the takeaway messages, an AI "special guest," developed in collaboration with the University of Tokyo, presented an executive summary of the four sessions on AI-related themes.

Discussion
Following this, there was a discussion among the speakers.

Prof. Hassan noted that while there has been much discussion of government-industry-academia partnership, a missing key component is society. He also pointed out the need to acknowledge and support innovation coming from low and middle-income countries, where there tends to be less funding available for innovators.
Dr. Skipper suggested that STS *forum* should move more of its discussions towards addressing how to achieve the goals that the participants of STS *forum* agree are needed.

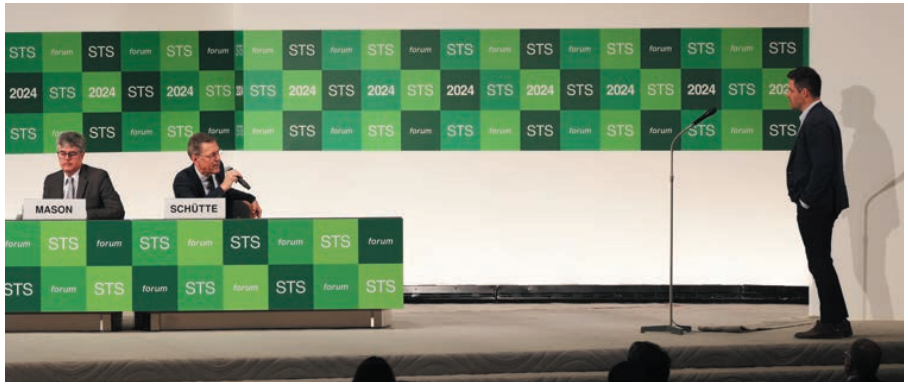
Dr. Mason was impressed by the AI summary and noted the rapid progress with which generative AI will continue to advance.

Prof. Mazur agreed and also highlighted the amazing pace of change. He believed that AI will clearly have a huge impact on society. He also suggested that it is useful to reflect on how previous technologies have affected society, noting how new technologies can atrophy certain skills, while creating new productivities, and the need to address the potential for AI to render certain jobs obsolete.

Q&A Session
Prof. Kleiner then invited questions from the audience.

The first question concerned what more needs to be done to address the problem of access to clean water. Dr. Schütte replied that there are energy requirements and a corresponding need for further investment. Technological development is also an aspect. Then there is the question of distribution and access to energy supply, funding, and technology.

Next, an audience member asked how the speakers who teach expect to change their teaching activities and the ways they evaluate students in the face of generative AI. Dr. Taylor explained that he allows his students to use ChatGPT while cautioning them that it makes mistakes, and that he has introduced more oral exams over written ones.
Another audience member noted the general consensus for the need for more international collaboration to address societal issues and asked what can be done to encourage national political and other leaders to embrace this reality. Dr. Skipper called on science



and technology leaders to change the discourse among politicians, who often view science and technology in terms of national competition, and promote unity in science and technology. Prof. Abdul Hamid noted that discussions at STS *forum* concern not only science and technology but also the linkage with political leaders and the formulation of evidence-based policies.

Next, an audience member pointed out the need to shift the interaction with young scientists from requiring them to continually justify themselves through publishing and granting mechanisms to enabling them to produce and act on their great ideas. Prof. Kleiner agreed and said that his goal, as a university professor, is to help his students surpass him and seek higher possibilities.

Closing Remarks

To close the session, Prof. Kleiner shared his conclusions from STS *forum*. Every day, there is a need to prove whether science and technology is intensifying problems or finding solutions for them, and there is a need for a new era of enlightenment driven by science and technology, including social sciences and humanities.

Closing Plenary Session: Science and Technology for the Future of Humankind

[Chair]

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

[Speakers]

Colwell, Rita R., Distinguished University Professor, University of Maryland Institute for Advanced Computer Studies, University of Maryland College Park; Professor, Johns Hopkins Bloomberg School of Public Health, U.S.A.

Liu, Mark, Founder and Chairman, J&M Copper Beech Ventures, U.S.A.; Former Executive Chairman, Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC), Taiwan

Komiyama, Hiroshi, Chairman, Science and Technology in Society *forum* (STS *forum*), Japan

Opening Remarks

Dr. Ismail Serageldin opened the session by introducing the speakers and inviting them to give their opening remarks.

Prof. Rita R. Colwell highlighted how this year's Annual Meeting of STS *forum* has been highly interdisciplinary, which is the future direction of science and technology. She also noted that AI, which was a major theme, is highly interdisciplinary. Additionally, she pointed out that many of the major challenges threatening human survival, such as climate change, water, and resources, are self-inflicted.

Serageldin, Ismail

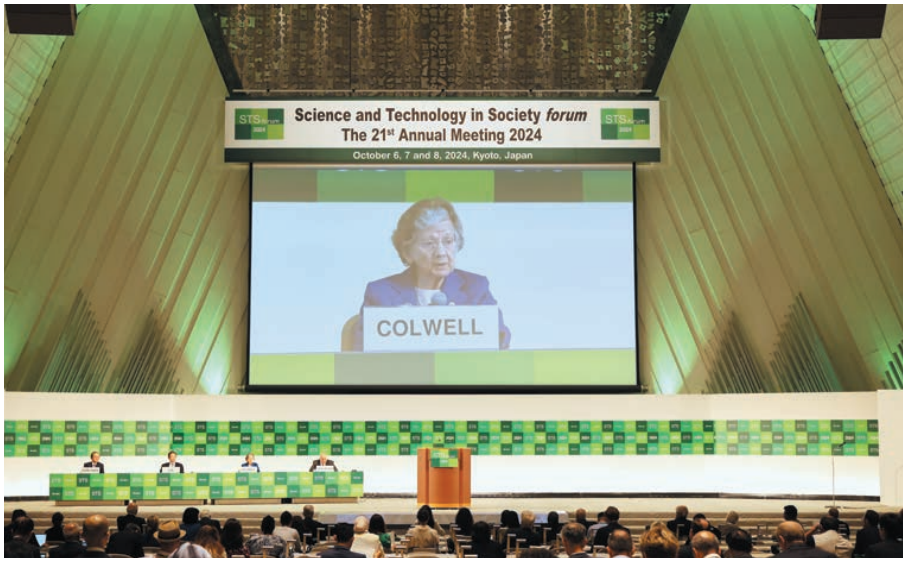
Prof. Colwell expressed the belief that, to ensure a future for humankind, the world needs persistence, resiliency, and innovation. Interdisciplinarity in science and technology is clearly the basis of humanity. Bringing together all of science and technology, including the social, behavioral, and economic sciences and technology, from the planning stages, not after the fact, is essential. AI, which is interdisciplinary, has permeated all of the discussions at this year's meeting, and the science and technology for the future of humankind

Colwell, Rita R.

includes truly weaving interdisciplinary aspects of all sciences.

As for challenges, in energy, there needs to be new and more efficient technologies, such as deep thermal and geothermal. The world will also surely face another pandemic in the future, so it needs to deal with and understand antibiotic resistance and the necessity of vaccines. In managing smart cities, there needs to be a more complete understanding of the intersection of ocean sciences and agriculture science since 50% of the global population resides in coastal zones. Furthermore, Earth system modeling should be enhanced, and Earth systems should be incorporated into politics and diplomacy.

Meanwhile, basic research is of tremendous value and warrants the same attention that translational research is afforded. Such research provides not only discoveries for the future but also develops the next generation of scientists, technologists, and engineers. Moreover,



social, behavioral, and economic sciences should be integrated in research from the initial stages, not just as an afterthought. There is no future for humankind without science and technology, but it is necessary to proceed with humility, not arrogance, and to avoid hubris, so we can move into the future successfully and safely.

Liu, Mark

Dr. Mark Liu began by pointing out that the traditional approach of business, which focuses on whether something can make money, may have worked in the past, but it is insufficient for tackling the challenges that threaten the world's future. The progress of today's science and technology has been turbocharged by advances in AI. There will be a transition in the future that brings the replacement of non-critical-thinking jobs by machines and robots. This will have huge societal implications in the same way that past leaps in science and technology have changed the world.
The current AI transition is only in its very early stages. The driving forces behind it have been continued innovation of AI algorithms, advances in semiconductor technologies, and massive availability of data on the internet. Even in the face of such change, the human capacity for curiosity and creativity cannot be stopped. Humans must embrace the challenge of this technological change, and do so with diversity, equity, and inclusivity.

The world has struggled with past transitions such as social media technology and its business models. Alongside breakthroughs in science and technology, we need to find the right timing for public policy implementation. The responsibility for public policy lies with professionals, politicians, and academia, but they often cannot keep up with advances in technology and business model changes. Policymakers must bet on the proper timing of policy implementation while still ensuring a rapid pace of innovation.

In today's geopolitics, too much focus is placed on national priorities and national competition. Open dialogue and collaboration are essential for good science, and there is a need to put common interest ahead of fear of competition. Engineers and business leaders need to engage more with think tanks, governments, and academics to advance government policy to keep up with technological change.

Dr. Serageldin stated that humanity has never been in such a fraught situation, with conflicts proliferating around the world. Development cannot occur without real peace and a just society with equality and security. There is a special role for women to play in this, as artisans of peace, and discrimination against women must be removed from all fields.

Geopolitical tensions are impacting possibilities for global cooperation, all while global action is critical to dealing with the global problems we face. Issues such as hunger and poverty are increasing again as well. Meanwhile, climate change continues to have dramatic impacts on the world. There is a need not just for climate mitigation, but also adaptation and resilience.

The participants in STS *forum* represent a coalition of the caring, who are reaching out to each other and who believe in the ability to address the aforementioned issues by mobilizing and deploying science and novel technologies. Nevertheless, the challenges are steep and getting steeper. Besides science and technology, health, education, and the rest of humanity must also be engaged.

Continued advances in science and technology hold huge promise. Still, it is vital that we nurture technology and innovation and mobilize them for the benefit of humankind

and natural ecosystems. This can only be achieved through dialogue among government, academia, and business.

The participants of STS *forum*, as a coalition of the caring, should advocate concern for the human family, sustainable development, and the prevailing of international law. We must combine the wisdom of elders and the vigor of youth. There are many struggles ahead, but we must continue our journey together at the next STS *forum* and beyond, while bringing what we gained from this year's interaction back with us and utilizing those insights in our respective fields.

Komiyama, Hiroshi

Finally, Prof. Hiroshi Komiyama closed the session.
He expressed his great love for STS *forum* and the optimism that the participants always instill in him. Prof. Komiyama stressed the continued need for STS *forum* and its contributions. Finally, he thanked the participants for their attendance and expressed his hope that he would see them again next year at the 22nd Annual Meeting of STS *forum*.

Concurrent Sessions

Energy
Action for Net-Zero Emission

[Chair]
Budil, Kimberly S., Laboratory Director, Lawrence Livermore National Laboratory (LLNL), U.S.A.

[Speakers]
Terazawa, Tatsuya, Chairman and CEO, The Institute of Energy Economics, Japan (IEEJ), Japan
Falk, Adam, President, Alfred P. Sloan Foundation, U.S.A.
Piketty, Laurence, Deputy Chairman, French Alternative Energies and Atomic Energy Commission (CEA), France
Lei, Yanli, Professor, ISO/TC 8/WG 15 Manager & Convenor, Ocean Negative Carbon Emissions and Carbon Neutrality; Institute of Oceanology, Chinese Academy of Sciences; Manager & Convenor, TC8/WG15 Ships and marine technology/Ocean Negative Carbon Emissions and Carbon Neutrality (ONCE-CN), International Organization for Standardization (ISO), China
Parris, Rex, Mayor, City of Lancaster, California, U.S.A.
Konishi, Satoshi, Co-Founder, Representative Director, Chief Executive Officer and Chief Fusioneer, Kyoto Fusioneering Ltd., Japan

Opening Remarks

The chair opened the session stressing the urgency of transitioning to a net zero emission world to address climate change impacts. Growing energy demand, intermittency of renewables, carbon dioxide removal strategies and continued fossil fuel use were some of the challenges mentioned. The chair highlighted the importance of diverse decarbonization pathways, community engagement, and international cooperation to overcome social and technical obstacles in this transition.

Budil, Kimberly S.

The speakers continued with the importance of considering timeframes, development stages, and regional differences in carbon neutrality strategies. Short-term (to 2030), mid-term (to 2040), and long-term (to 2050 and beyond) horizons were introduced, stressing the need for broad deployment at scale to significantly impact global CO_2 emissions. Technologies available in advanced economies may only be future options for developing countries. They noted several technologies ready for short-term deployment and emphasized four key points: starting deployment now, recognizing long implementation timelines before broad deployment, dispersing existing technologies to emerging economies, and maintaining a diverse technology portfolio to account for uncertain development timelines.

Next, speakers emphasized three key principles to ensure equity in the energy transition: addressing power relations that may reproduce inequalities, involving local communities from the outset, and forming strong partnerships between researchers, industries, and communities. They provided examples of funded projects illustrating these principles, including studies on vulnerable communities, microgrid development, and various energy transition strategies in the United States.

The speakers then focused on France's approach to net zero emissions, focusing on low-carbon technologies and supporting industry. Key technological areas include nuclear energy, hydrogen, sustainable fuels, solar photovoltaics, batteries, and smart grids. France's ambitious nuclear policy aims for reduced energy consumption and increased low-carbon production, including new reactor construction and innovative projects. While many technologies for 2030 targets exist, some require scaling, and 45% of innovations for 2050 goals are still in development, underlining the crucial role of research in the energy transition.

Following this, a program, Global-ONCE (Ocean Negative Carbon Emissions), based on a Microbial Carbon Pump (MCP) scenario was introduced, which aims to enhance ocean negative carbon emissions and carbon cycling to address climate change. The ocean absorbs over 26 percent of human-produced carbon annually. Key practical applications include increasing ocean alkalinization and carbon-neutral aquaculture etc., which demonstrate feasible, legal, and low-cost methods with great potential to upscale in the future. Additionally, the program focuses on developing international standards for ocean carbon emission and carbon neutrality techniques through International Organization for Standardization and International Maritime Organization collaborations.

The speakers then discussed the importance of partnerships between government, industry, and academia in advancing alternative energy technologies. They stressed that the transition to cleaner energy is both technologically viable and economically beneficial, citing Lancaster City's improved financial standing as evidence of success in alternative energy initiatives.

Finally, the speakers discussed fusion energy's potential and its implications for global sustainability, especially in developing and emerging countries. The need for equitable distribution of clean energy technologies to developing nations and the importance of

self-sustained energy systems worldwide were two points that required further attention. The speakers concluded the opening remarks stating that addressing these challenges requires not only technological solutions but also cultural, economical and social understanding.

Discussion

Beginning the discussion session, participants stressed the urgency of deploying current technologies, acknowledging the need for multiple solutions tailored to local conditions and strengths. They highlighted the potential for cost-sharing and leveraging regional advantages in areas like renewable energy and storage. It is important to develop support structures, including workforce development, supply chain management, and regulation, alongside technology implementation to prevent future delays.

Participants returned to the example of Lancaster's successful implementation of solar energy, focusing on transparent decision-making and supportive regulations. This example showed how new energy sources can create positive economic outcomes. Contrasting this with cities not utilizing their resources effectively, they suggested that municipality-specific solutions, supported by funding and transparency, could drive progress.

The conversation then centered on the energy transition as a social issue, emphasizing the need to build trust among stakeholders. Participants noted insufficient communication regarding nuclear energy and renewables, potentially leading to community rejection. Universities and research institutes were identified as trusted partners to improve communication. They explored new applications for nuclear reactors and discussed energy use prioritization, highlighting the growing importance of social scientists in addressing these challenges.

Next the discussion covered the energy transition and technology, emphasizing improvement of existing technologies alongside new ones, particularly biomass in the Global South. Carbon sequestration, economics, and incentives in technology adoption were discussed. They discussed accelerated fusion technology development and explored challenges in industrial adoption, suggesting a carbon tax as a potential solution to make carbon sink in Global South to trade.

Following up on new technologies participants covered ocean-based carbon dioxide removal techniques using microorganisms, which emulate natural ocean processes and have shown promise in laboratory settings. Concerns raised by participants regarding the effectiveness,

potential side effects, and costs of marine zero-carbon solutions were addressed by the ONCE approaches. There was consensus on the desire to develop and scale these technologies worldwide to enhance carbon dioxide removal efforts.

The conversation then shifted back to the idea of replicating net-zero communities globally, acknowledging the need for localized solutions such as hydrogen where solar power is less viable. Infrastructure development and its economic hurdles were emphasized. Participants underscored the importance of diverse energy sources and effective public outreach focusing on economic advantages and safety. Suggestions included integrating energy education in school curricula to boost acceptance. The need to expedite technology adoption through economic incentives and supportive policies was another idea that was shared among the participants.

Lastly, public acceptance was recognized as vital for implementing current and future energy technologies. The participants addressed scaling obstacles, noting governments' role in facilitating deployment. They reiterated international collaboration and a diversified approach as important parts of the effort to accelerate the energy transition. They expressed optimism about fusion technology's potential to progress from concept to practical demonstration within a decade or two, possibly offering a sustainable global energy solution and provide negative carbon balance in the long term.

Energy

Investment and Financing for Energy Transition

[Chair]

Keller, Martin, Director, National Renewable Energy Laboratory (NREL), U.S.A.

[Speakers]

Kanda, Masato, Special Advisor to the Cabinet and to the Ministry of Finance of Japan (former Vice Minister of Finance for International Affairs), Ministry of Finance, Japan; Chair, Corporate Governance Committee, Organisation for Economic Cooperation and Development (OECD)

Hildebrand, Philipp, Vice Chairman, BlackRock, U.S.A.

Patel, Ketan J., Chair, Force for Good; Chief Executive Officer, Greater Pacific Capital LLP, U.K.

Heslin, Lex, CEO, ENSO Infrastructure, LLC, U.S.A.

Motwani, Sulajja Firodia, Founder & CEO, Kinetic Green Energy & Power Solutions Limited; Chairperson, Electric Vehicle Forum, Federation of Indian Chamber of Commerce, India

Streiffer, Stephen, Laboratory Director, Oak Ridge National Laboratory, U.S.A.

Opening Remarks

The chair opened the session by introducing the panel of speakers and discussing the Paris Agreement's goal of limiting global temperature rise. They emphasized the need for substantial investment and cited an estimate of $150 trillion to achieve the current emission reduction targets. The chair highlighted the surge in clean energy technology manufacturing, particularly in China, the US, and the EU, but noted that current investment levels are still insufficient. They stressed the importance of private sector funding and government support in creating appropriate policy environments and distributing risk.

Keller, Martin

The speakers emphasized the urgency of global energy transition from economic and social perspectives. Three key areas were focused on: finance, supply chain, and technology. In finance, there is a need for diversified approaches to climate finance and increased private sector participation. The Innovative

Finance Facility for Climate in Asia and the Pacific of the Asian Development Bank was brought up as an example of financial innovation. Regarding supply chains, the speakers noted the importance of diversification to mitigate risks and enhance participation from developing countries. Lastly, on technology, there is a need for long-term planning and the development of next-generation technologies.

The speakers then discussed the evolving landscape of energy policy, noting the emergence of energy pragmatism in response to recent global events. They communicated that the energy transition is a multi-decade phenomenon characterized by uncertain shifts and driven by technology, public stance, and investor-consumer preferences. The speakers highlighted opportunities in transition-related themes, including artificial intelligence and data centers, early-stage low-carbon technology, and blended finance for emerging markets. The financial and private sectors can be key drivers in supporting government policies, but they cannot deliver the transition alone.

Next, speakers shared their perspectives on the energy transition as part of a broader civilizational shift. They said that the transition to renewable energy sources is inevitable and will be funded, the main question being the timing and efficiency of the process. The potential of fusion energy as a future power source was introduced, as well as the role the private industry and government competition play in driving innovation. They noted the ongoing competition between major economies in developing key technologies for the future, including AI and energy transition solutions.

Hydrogen-based solutions were discussed next with examples from companies' approaches to developing microgrids and multimodal fueling stations that combine battery and hydrogen technologies. The speakers shared financing strategies used for certain projects, which included various debt and equity sources. They weighed the importance of environmental credits in project economics and highlighted the potential for cost reductions in green hydrogen production as manufacturing scales up.

The speakers then discussed that 25-30% of global emissions are contributed by vehicular emissions and thus, transition to zero-emission electric mobility is an important element of green transition. Further, it was discussed that while most developed nations are working towards aggressive goals for a transition to e-mobility, it is equally important to support advancement of e-mobility in the emerging markets. This will require making e-mobility accessible and affordable for mass deployment, especially in developing economies. They highlighted the significant contribution that transport has in reducing global emissions and the potential green impact of mass electrification. The speakers suggested a combination of blended finance, supported by leading global financial institutions, green bonds, and private equity investments to accelerate the green transition in both developed and developing markets.

The speakers concluded the opening remarks by highlighting the urgency of addressing climate change, particularly considering potential tipping points. They emphasized that

energy transition strategies must be tailored to different regions and political economies and stressed the importance of public-private partnerships across the entire spectrum of research, development, and deployment. There are also notable challenges in nuclear energy development, including high investment costs and technological hurdles. The speakers lastly touched on the potential and challenges of fusion energy, stating that current renewable technologies are likely transitional steps towards future energy sources that are yet to be fully realized.

Discussion

The chair opened discussions by addressing the government's perspective on the largest hurdle for increased industry investment to accelerate the energy transition in Japan. The participants emphasized the challenge of balancing public and private sector interventions, noting that government involvement should be justified for infrastructure development, framework creation, and initial subsidies. They highlighted the importance of maintaining long-term stability for investment environments and stressed the need for a balance between fundamental and applied research, mentioning Japan's efforts in nuclear power and fusion technology.

The challenges of mobilizing capital for emerging markets were discussed next, with participants highlighting the need to raise risk levels to Organization for Economic Co-operation and Development standards. They reiterated the importance of blended finance and the fiscal constraints faced by governments. They mentioned various approaches to risk reduction, such as first-loss risk absorption and minimum guarantees but noted that solving the problem of capital flow into emerging markets is crucial for achieving climate goals.

Next, the participants presented an optimistic view of funding the energy transition, stating that it will happen, with timing and efficiency being the main considerations. They emphasized the shift from fossil fuels to renewables and potentially fusion energy. Then, the participants highlighted the role of private industry in driving innovation and funding, noting the fierce competition among major economies for future technologies. They ended this portion by stressing the importance of scientific breakthroughs and the need for a supportive ecosystem to translate research into economic benefits.

Following that discussion, participants addressed the current state and future prospects of hydrogen technology. It was noted that while green hydrogen production is currently expensive, prices are expected to decrease significantly with scaling and automation. The

need for government support on the off-take side was emphasized, suggesting contracts for differences and long-term off-take agreements to make hydrogen projects financially viable.

The participants turned to the topic of the electrification of two and three-wheelers in developing countries, where e-mobility will contribute to reduction in air pollution but also make mobility more affordable to the population. The focus on mass transport vehicles and the progress made in achieving price parity with conventional vehicles was discussed. Government incentives, scale, and local supply chain development all play a role in reducing costs. Also discussed were the financing challenges for both manufacturers and consumers, specifically the need for support from international financial institutions and innovative financing mechanisms. Once e-mobility achieves critical mass through such financial innovations, then the availability of finance from commercial banks will become more prevalent.

The participants closed by discussing the role of national laboratories in advancing energy transition technologies. They stressed the importance of addressing interlocking problems such as clean energy, sustainability, and climate change. The labs' ability to maintain expertise at scale and bridge the gap between basic and applied research is crucial for the future. The need for international cooperation and aggregated resources to tackle the magnitude of energy transition challenges effectively cannot be understated.

Energy
Solutions to Renewable Energy Intermittence

[Chair]

Tanguy, Philippe A., CEO, HTEC Quebec inc.; Adjunct Professor and Past University President, Polytechnique Montreal, Canada

[Speakers]

Cochran, Jaquelin, Associate Lab Director (acting), Strategic Energy Analysis and Decision Sciences, National Renewable Energy Laboratory, U.S.A.

Kobayashi, Hideaki, Professor, Institute of Fluid Science, Tohoku University, Japan

Ingþórsson, Ágúst Hjörtur, General Director, Icelandic Centre for Research - Rannis, Iceland

Sebald, Gael, Professor, INSA Lyon - CNRS, France; Visiting Professor, Tohoku University, Japan

Romero-Lankao, Patricia, Canada Excellence Research Chair in Sustainability Transitions, Sociology, University of Toronto - Scarborough, Canada

Opening Remarks

The chair opened the session by introducing the topic of building a new energy system, primarily based on renewable energy sources, and emphasized that this system must be resilient, operate continuously, and be affordable for both industry and the population. The transition from legacy grids built around large, controllable electricity generators to systems integrating intermittent renewable energy sources creates various challenges, including environmental, social, economic, and technical pressures. The chair outlined several strategies to address these issues, including energy storage, demand response, consumer-focused incentives, grid interconnection, and improved forecasting and market tools.

Tanguy, Philippe A.

The speakers began with the evolution of managing renewable energy on the grid over the past 15 years. They explained how concerns about managing variability have shifted from hour-to-hour fluctuations to daily and seasonal balancing challenges. The introduction of battery storage has dramatically improved the ability to manage daily

variations, but seasonal balancing remains a significant challenge and opportunity for new R&D. Important factors include power system flexibility as well as the need for low-capital cost solutions for seasonal energy storage, such as hydrogen or biogas.

Next, the speakers focused on situations in Japan and East Asia, highlighting three key issues: grids of power and energy carriers, geopolitical characteristics, and zero-emission thermal power. They also discussed the challenges of limited renewable energy resources in the regions and the need for improved power grid flexibility. They emphasized the potential of zero-emission thermal power, particularly using hydrogen and clean ammonia, as a solution to intermittency issues in Asia.

The speakers also considered the European perspective on renewable energy intermittence, emphasizing the role of public policies in promoting solutions. They highlighted the EU's Innovation Fund as an example of a competitive funding scheme aimed at stimulating innovation and deployment of net-zero technologies, and discussed the potential of geothermal energy as part of the solution to renewable energy intermittence, particularly in Europe and Asia.

The speakers next considered materials physics for energy conversion and storage. They discussed the potential of innovative materials for electrical energy storage, and thermal energy storage technologies for managing renewable energy intermittence. It is important

to consider the entire energy supply chain and the potential for direct use of thermal energy storage for space heating and cooling.

Lastly, the speakers addressed the societal aspects of grid development and renewable energy integration. The consideration of equity and access issues, particularly in developing countries and among disadvantaged and vulnerable communities, was noted as an ongoing issue that requires more attention. The speakers called for a broader perspective that includes social scientists and humanities experts in the development of grid technologies. They also emphasized the need to address political, institutional, and cultural challenges in addition to technical issues when designing and implementing new grid systems.

Discussion

To begin the discussion session, participants focused on the availability of renewable energy on different continents. They noted that Europe has abundant renewable energy sources, with wind in the north and solar in the south, interconnected by grids. In Southeast Asia, solar energy is abundant, but most countries have regulated markets, requiring careful consideration when adopting new technologies. Key challenges discussed included the need for proper grid sizing, sustainability across seasons, and high investment costs. Solutions proposed included interconnections between countries, integrated monitoring and control systems, and investor government incentives.

The participants also highlighted the importance of considering geographical variations within countries when determining appropriate energy sources and policies. They discussed the potential for exporting electricity or energy-intensive products, and how connectivity varies by region. They noted that public perception of energy types differed between countries, affecting policy implementation and emphasized the need for strategies tailored to specific regions and their unique challenges.

The participants also cited societal pressure to address climate change, the push for electrification in transportation, and the need to decarbonize energy production. They highlighted the strain on current grid structures, the importance of including affected communities in decisions about new energy facilities, and the need to consider energy security and potential supply chain disruptions when expanding the grid. They also stressed the importance of inclusive participation in grid expansion strategies.

The participants then moved on to the difficulties of dealing with intermittency in renewable energy sources, particularly in Japan. They explored the challenges of insufficient land for solar and wind installations and the potential for international energy connections. Also, they touched on the role of energy carriers like hydrogen and ammonia, and the importance of maintaining good international relationships for energy trade. The need for better communication between policymakers and technologists, specifically when considering the potential replacement of aging coal-fired plants with nuclear power was also highlighted.

Closing out the session, the participants emphasized the value of suboptimal solutions that allow for diverse technologies rather than one-size-fits-all approaches. They discussed the challenges of integrating end-of-life battery systems back into the grid and speculated on the potential impact of AI on energy demand, suggesting that if energy demand for AI decreases over time, initial investments in energy delivery for AI could be repurposed for hydrogen production.

Earth and Commons
Digital Twins of Ocean

[Chair]

Leinen, Margaret, Director, Scripps Institution of Oceanography UC San Diego; Vice Chancellor, Marine Sciences, University of California, San Diego, U.S.A.

[Speakers]

Bye, Bente Lilja, Founder and CEO, BLB, Norway

Clough, Lisa, Deputy Division Director, Division of Ocean Sciences, U.S. National Science Foundation, U.S.A.

Yamato, Hiroyuki, President, Japan Agency for Marine-Earth Science and Technology (JAMSTEC); Professor Emeritus, The University of Tokyo, Japan

Arnaud, Alain, Head of Digital Ocean Program, Mercator Ocean international (MOi), France

Mashayek, Ali, Associate Professor, Department of Earth Sciences, University of Cambridge, U.K.

Masumoto, Daiki, Fellow, SVP, Fujitsu Research, Fujitsu Ltd., Japan

Staneva, Joanna, Head of Department, Institute for Coastal Systems, Department "Hydrodynamics and Data Assimilation", Helmholtz Center HEREON, Germany

Opening Remarks

The chair opened the session by explaining that digital twins are virtual copies of physical objects or systems using real-time data to monitor and simulate behavior. The United Nations (UN) Decade of Ocean Science for Sustainable Development, which began in 2021, set a goal to develop Digital Twins of the Ocean by the end of the decade. This initiative has stimulated the ocean science community to increase work on building digital twins at various scales, from general climate change models to smaller, specific use cases.

Leinen, Margaret

The speakers discussed different types of digital twins, including those providing situational overviews and those incorporating various models and data types. They emphasized the complexity of the ocean system, involving geophysical, biological, and chemical aspects, as well as human activities. The speakers discussed the value of digital twins in enabling decision-makers to evaluate conflicting interests, such as balancing ecosystem preservation with industrial activities and tourism.

The speakers emphasized the usefulness of digital twins, particularly for real-time information. They noted that ocean data are uniquely expensive and often lagged, highlighting the need for more affordable and accessible sensing technologies. The speakers mentioned the potential of new sensors, such as undersea cables, to provide vast amounts of data. They also stressed the importance of involving diverse voices in developing digital twins and acknowledged the need to balance open science with national security concerns related to data.

The speakers then noted that Digital Twins of the Ocean are essential tools for deepening scientific understanding of the ocean. They emphasized the importance of integrating ocean observation data and simulations to support decision-making on issues such as climate change adaptation and disaster response. The speakers highlighted the need for international cooperation and enhancing ocean observations and observational technologies development to address data gaps, particularly in polar regions and the deep sea, and on key processes such as the response of ecosystems to changes in the marine environment. They also pointed out the importance of data sharing, interoperability on data and interface, as well as capacity building for maintaining and using Digital Twins of the Ocean.

The speakers also emphasized the potential of digital twins to impact policymaking and highlighted the importance of what-if scenarios. They explained how digital twins allow testing solutions in a virtual environment before applying them in reality. The speakers stressed the significance of communication between scientists and the broader world in elevating ocean knowledge to a new level, noting that digital twins have helped garner more interest and understanding from policy makers and stakeholders.

Next, the speakers advocated for the involvement of social sciences from the outset. They conveyed the importance of connecting with end-users and stakeholders early in the process to ensure the relevance and applicability of digital twins. The speakers emphasized the importance of making digital twins accessible to less developed countries, suggesting the use of cloud computing to democratize access to ocean data and analysis.

The speakers further elaborated on their approach to Digital Twins of the Ocean, focusing on different use cases such as maintenance of marine structures, conservation of biodiversity and blue carbon utilization. They highlighted new technologies, including underwater 3D measurement tools and deep learning techniques for recognizing underwater organisms in murky waters, emphasizing their potential for estimating carbon dioxide absorption by marine ecosystems.

Lastly, the speakers provided an overview of specific aspects of the UN Ocean Decade. They outlined its structure, including its focus on sustainable observations, integrating AI, and building capacity. The speakers also stressed the need for education and training programs to ensure the sustainability of the use of digital twins worldwide, highlighting the program's aim to reach and involve people from all regions, including less developed areas.

Discussion

In the group discussion, the participants highlighted the significant potential of Digital Twins of the Ocean to bridge local and global knowledge, emphasizing that funding is crucial for both development and effective stakeholder engagement. They stressed the need for affordable and scalable sensors to provide key data in critical areas while raising questions about who should decide what is needed and who should supply these sensors. The participants emphasized the necessity of wide data sharing among organizations, not just

researchers, and called for global standards and open-use conditions for data. However, the counter-pressures between sensor availability, data collection, ownership, and the need for free dissemination was conveyed. The participants also discussed the challenges of model validation, noting that key ocean dynamics are not yet fully understood, and that machine learning technology can produce confident but unreliable outputs.

The discussion also revolved around the importance of diverse partnerships in the development of Digital Twins of the Ocean, including collaborations between academics and for-profit entities. The participants explored innovative ways to use digital twins for public engagement, suggesting the potential of incorporating them into games or movies to help people understand the importance of oceans. They also addressed the challenges of real-time data communication from oceans to digital twins, proposing that near real-time updates, with a delay of a day or two, might be more feasible and effective.

The discussion expanded to cover issues related to data harmonization, intellectual property rights, and cybersecurity in the context of open digital twin initiatives. The participants recognized the complexities of balancing open data and technology sharing with the need to protect intellectual property and ensure cybersecurity. The importance of addressing the global commons data problem was conveyed, with calls for restructuring UN institutions to better support scientific data sharing. The Argo program was cited as a successful example of international cooperation in data collection, noting that no country has restricted the floats when those drift into its territory while collecting data.

In the final part of the discussion, the participants highlighted the need to integrate natural systems models with socioeconomic models to develop pathways for increasing social welfare. They noted that this integration could lead to positive policy development. Specific areas of focus included the Arctic region, where US-Russia interests complicate data handling, and the deep ocean, where increased knowledge could revolutionize health and agricultural practices. Participants emphasized that this holistic approach, linking natural and socioeconomic systems, is crucial for developing policies that truly benefit human welfare and effectively harness the immense potential of Digital Twins of the Ocean.

Earth and Commons
Food and Water Security

[Chair]

El-Beltagy, Adel El Sayed Tawfik, Chair, International Dryland Development Commission (IDDC); Professor, Arid Land Agricultural Graduate Studies & Research Institute (ALARI), Ain Shams University, Egypt

[Speakers]

Fowler, Cary, Special Envoy for Global Food Security, U.S. Department of State, U.S.A.

Taniguchi, Makoto, Deputy Director General, RIHN Center, Research Institute for Humanity and Nature (RIHN), Japan

Friedrich, Bruce, Founder and President, The Good Food Institute, U.S.A.

Mukherji, Aditi, Director, Climate Change Impact Platform, One CGIAR, Kenya

Toubia, Didier, Co-Founder and Chief Executive Officer, Aleph Farms, Israel

Zarur, Andrey J., Co-Founder, President & CEO, GreenLight Biosciences, Inc., U.S.A.

Opening Remarks

The chair opened the session by emphasizing the critical global challenges including the impact of climate change related to food, water, and energy security in the context of rapid population growth. The chair highlighted that the world population is projected to reach 10 billion, necessitating a 70% increase in food production. However, this challenge is compounded by an expected reduction in food production by 20-50%. To address this, significant transformations in agriculture are required, driven by intensive knowledge to boost production, optimize water use, minimize food losses, and promote dietary changes. Adopting climate-smart agriculture (CSA) is crucial for ensuring national food security, increasing productivity and income, reducing agriculture's contribution to climate change, and enhancing resilience to climate variability. A drastic reduction in meat and dairy consumption is urgently needed to decrease methane emissions, potentially through gene editing technologies like CRISPR-Cas9 or the production of synthetic proteins. The transition

El-Beltagy, Adel El Sayed Tawfik

to precision agriculture, smart agriculture, and Agriculture 4.0 is essential, requiring investments to implement and disseminate new technologies and innovations.

The speakers noted that over 750 million people are food insecure, and 3 billion are unable to afford a nutritious diet. They highlighted the alarming statistic of 60 million children under five being cognitively and physically stunted, emphasizing the long-term impacts on economic development and social stability. The need for transformative research and development (R&D) was emphasized, as agricultural R&D budgets have continued to stagnate in many countries.

The speakers focused on the interconnectedness of food and water security through global food trade. They presented research on virtual groundwater trade, showing how food production and trade impact groundwater depletion globally. The speakers advocated for the use of models that analyze synergies beyond just food and water, to include energy, land use, and labor for improving both food and water security.

The inefficiencies of conventional meat production and the potential of alternative proteins to address climate and food security challenges were also discussed. The speakers explained that conventional meat production requires significantly more resources, with chickens needing about nine calories of input for one calorie of meat, and cows requiring about 40 calories. They emphasized the need for more research funding to make alternative

proteins competitive on taste and cost, drawing parallels to the development of renewable energy and electric vehicles.

The speakers conveyed the critical but often overlooked role of water in climate change discussions, particularly related to food security. They pointed out that water was not prominently featured in climate negotiations until recently, despite its fundamental role in how people experience climate change impacts. The speakers outlined how climate change affects every component of the water cycle, including precipitation patterns, groundwater, and water pollution. They emphasized that these changes disproportionately affect vulnerable populations, including smallholder farmers who rely on rain-fed agriculture.

The speakers then discussed the need to diversify and decentralize animal protein production to increase food system resilience and sustainability. They highlighted the significant contribution of animal products, particularly livestock, to methane emissions and their extensive use of land and water resources. The speakers advocated for investing in new production methods like cultivated meat, alongside conventional agriculture and regenerative practices, to both optimize resource uses and meet future demand sustainably.

Finally, the speakers discussed the lack of innovation in agricultural technologies. They contrasted the rapid approval process for life-saving drugs with the lengthy, uncertain regulatory process for new agricultural products. The speakers argued that this regulatory uncertainty deters investment and entrepreneurship in agricultural innovation, leading to a significant decrease in new crop protection products. They called for a more efficient, predictable regulatory framework to encourage the development of sustainable agricultural solutions, suggesting that the agricultural industry should learn from the pharmaceutical industry's approach to regulatory processes.

Discussion

In the group discussion, the participants emphasized the need for regulation to keep pace with technology and the development of frameworks to incentivize investment in water conservation, biodiversity, and new technology adoption. They stressed the importance of directing capital towards solving core problems in food and water security, particularly in food-insecure regions. The participants also noted that while significant funds have been raised for climate-related initiatives, insufficient money is being allocated to address fundamental issues in food and water security.

The participants also focused on water security, highlighting the concept of climate velocity and the sensitivity of the hydrological cycle. They discussed the multi-layered nature of water-related problems and the importance of considering the food-water-energy nexus. The participants also touched on water quality issues, digital water management, and the critical role of human behavior in addressing water security challenges. They emphasized the complexity of water-related issues, describing them as compound hazards that require detailed analysis. The human factor was underscored as a critical element in addressing water security issues.

Novel food production systems were also discussed, with the participants exploring the diversification of protein sources beyond conventional methods. They emphasized the need for close collaboration between regulatory efforts and industry in designing frameworks for novel production systems and foods. The participants also addressed challenges in making food production more sustainable, including economic incentives and demographic issues in agriculture.

The participants delved into the debate between meat and alternative proteins, acknowledging the need to consider factors beyond calorie conversion, such as specific amino acids and micronutrients. They discussed various water-related innovations and questioned the disparity between agricultural and health funding at government and university levels. The

participants questioned why agricultural funding lags behind health funding and discussed the challenges of increasing food production to meet the needs of a growing and more affluent population.

The importance of multidisciplinary integrated thinking in solving food and water issues was also discussed. The participants emphasized the need for investment in human resources capable of driving science-based decisions in food and water systems. They also highlighted the need to focus on long-term challenges, such as water scarcity in the coming decades, and suggested incorporating traditional foods, like millets in Africa, as part of resilient and sustainable food systems.

The chair summarized the critical challenges facing global food and water security, highlighting the projected decrease in food production despite increasing demand, exacerbated by diminishing water resources. The chair emphasized the need for strong focus on regulatory legislation, biosafety, and public awareness to improve diets and reduce consumption, along with the inadequacy of current international agreements and funds to address climate change impacts, particularly for vulnerable nations. The need for knowledge-based sustainable development including enhanced bio-economy, improved education, and stronger research institutions to guide policy makers was stressed. The chair also elaborated that during COP 29, there is a need to establish an early warning system to cope with climate change, secure funding to address loss and damage, and launch the Sharm El-Sheikh program on transforming agriculture and scaling up climate adaptation.

Earth and Commons

Circular Economy toward End of Mining

[Chair]

Blanco Mendoza, Herminio, President, IQOM, Inteligencia Comercial; former Minister of Trade and Industry, Mexico

[Speakers]

Koundouri, Phoebe, Professor, Department of International & European Economic Studies, Athens University of Economics and Business & Technical University of Denmark; World Council of Environmental and Resource Economists Associations; SDSN Global Climate Hub; AE4RIA; President, World Council of Environmental and Resource Economists Associations; Chair of the SDSN Global Climate Hub, Greece

Phapugrangkul, Pongsathon, Chief Administrative Expert and Acting Director of Biodiversity Research Centre (BRC), Thailand Institute of Scientific and Technological Research (TISTR), Thailand

Vasara, Antti, CEO, VTT Technical Research Centre of Finland Ltd., Finland; Board Member, European Association of Research and Technology Organizations (EARTO), Belgium

Tanaka, Shogo, Director, Resource Efficiency and Circular Economy Division, Ministry of Economy, Trade and Industry, Japan

Matsubae, Kazuyo, Professor, Graduate School of Environmental Studies, Tohoku University, Japan

Opening Remarks

Blanco Mendoza, Herminio

The chair opened the session by discussing the concept of circular economy (CE) in relation to mining. It was emphasized that while progress is being made toward reducing the need for mining, complete elimination is not yet feasible. Using examples from the steel and plastics industries, the chair illustrated how CE practices are being implemented, but noted that challenges remain in certain sectors. The chair highlighted successful initiatives, such as the construction of PET recycling plants in Mexico and a joint venture between Mitsubishi Corporation and JX Advanced Metals Corporation aimed at realizing CE for various industries.

The speakers emphasized the connection between CE and the United Nations Sustainable Development Goals (SDGs), noting that CE is a key component of sustainability strategies. The speakers presented data driven methods showing correlations between CE indicators and SDG implementation, particularly in Europe. They also discussed the performance of mining companies in Environmental, Social, and Governance (ESG) criteria, highlighting that ESG-winners, companies with good ESG performance, tend to outperform their peers in stock market returns. This effect is even stronger in companies with a good performance in CE practices.

The speakers discussed the potential benefits of CE practices, including job creation and environmental protection, while also acknowledging the challenges faced by certain industries and regions during the transition. They stressed the importance of innovation, collaboration, and shared commitment to sustainable practices, citing Thailand's net-zero emission urban innovation ecosystem project as an example of multi-stakeholder cooperation in promoting CE principles.

The speakers also focused on the critical role of metals in the ongoing energy transition and digital transformation. They highlighted the increasing demand for materials such as nickel,

cobalt, lithium, and rare earth elements, noting that recycling alone cannot meet these growing needs. The speakers discussed the European Union's Critical Raw Materials Act, which sets targets for extraction, processing, recycling, and imports of critical raw materials.

Japan's CE policy was also discussed, which traces its origins to the 1950s when the country faced challenges in waste management. The speakers outlined three key factors for realizing CE: collectability, cost efficiency, and creating demand for recycled materials. They focused on Japan's success in reducing final waste dumping volumes and its efforts to address economic security and carbon dioxide neutrality concerns.

Lastly, the speakers discussed the importance of understanding metallurgy and thermodynamic principles in recycling metals such as aluminum, magnesium, and titanium. They conveyed the challenges of controlling impurities in these metals and emphasized the role of market mechanisms in motivating businesses to control contamination. The speakers stressed the significance of knowledge accumulation about supply chains and the need for international and interdisciplinary collaboration to create comprehensive data platforms that include environmental and social information.

Discussion

The participants emphasized the importance of quantification and identifying key performance indicators to realize CE. They noted the absence of internationally agreed upon metrics for CE, contrasting it with the well-defined targets for climate change, such as the 1.5 degrees Celsius goal. The participants expressed skepticism about developing uniform, internationally agreed upon indicators, suggesting instead that individual nations contribute according to their capacities, similar to the Nationally Determined Contributions in climate policy.

Additionally, the participants emphasized the critical role of social recognition and education in driving CE efforts. They highlighted the Japanese experience, where despite high recycling rates and strict waste separation practices, communities often resist paying premium prices for recycled products. This underscores the need for broader societal awareness and acceptance to realize true CE. The participants stressed the need for diverse perspectives, particularly from developing nations like India, and highlighted the importance of information transparency. Europe's leadership in CE efforts was recognized, but the participants noted the significant differences between European and Japanese contexts, emphasizing the need for tailored approaches.

The participants focused on the intricate relationship between energy and materials, suggesting that scientific breakthroughs could potentially eliminate the need for mining certain materials. They discussed the challenges of recycling, noting that even in advanced countries, only 10% to 20% of materials are recycled. The participants proposed pricing externalities via carbon tax implementation to encourage behavioral changes. They outlined a three-phase approach to address these challenges: a short-term focus on recycling and regulation, medium-term efforts to price externalities, and long-term reliance on scientific breakthroughs to create alternative resources. The participants expressed hope in emerging technologies such as nanotechnology, quantum computing, and AI to revolutionize resource use.

Final comments highlighted the critical need for specific skills to transition to CE. This led to a discussion on the importance of investing in upskilling, reskilling, and revising educational curricula in both developed and developing countries. The participants stressed the responsibility of governments to collaborate with companies in achieving these educational goals. The discussion also touched on the broader implications of transitioning to a circular or carbon-neutral economy, acknowledging that some industries may need to undergo significant transformations. This transition was recognized as not just a technical challenge but also a socioeconomic one, with potential impacts on employment and social structures. The participants cautioned against a dogmatic approach to CE implementation, noting that not all CE processes are necessarily carbon-positive or carbon-neutral. They emphasized the need for a balanced approach that considers the potential high costs and varying environmental impacts of different CE strategies.

Climate Risks
Resilient Society against Climate Risks

[Chair]

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

[Speakers]

Kimoto, Masahide, President, National Institute for Environmental Studies (NIES), Japan

Augustine, Lauren Alexander, Executive Director, Gulf Research Program, National Academies of Sciences, Engineering and Medicine; U.S.A.

Alcocer, Sergio M., President, Consejo Mexicano de Asuntos Internacionales (COMEXI); Professor, Institute of Engineering, National Autonomous University of Mexico, UNAM, Mexico

Opening Remarks

The chair began by explaining the focus on discussing how the participants can support the creation of resilient societies that can withstand climate risks. Extreme weather events driven by climate change are becoming harder to predict and more intense. As communities undertake rebuilding, understanding future risks will be essential. Science and technology have a critical role to play in understanding the increased risk and supporting recovery and resilience. Scientists, technologists and engineers must help policy makers and business leaders confront climate change more effectively with science-based solutions to mitigate the risks around the world, including through the use of AI.

Kearns, Paul K.

The speakers then discussed how scientists and engineers can communicate the connection between weather and climate change to the public, highlighting the recent efforts made in Japan. There is a challenge in society where there is a need to protect the environment, while the economy must be preserved. It is also essential to raise public concern and understanding, and that involves changing the structure of society itself. The public has to be

convinced to move towards a new society, but the most serious concern to the public is money. Social science also has to contribute to pushing people towards a new society.

The speakers then considered the question of what happens in the process of decarbonization when the economy is carbon dependent, or when the economy is built by climate change-related disasters such as economic shifts made in response to natural disasters. There is no easy choice between separating the need to produce energy and reducing climate risks. When we say we want to decarbonize, there are a lot of tradeoffs around the world, with layered issues that need to be addressed. The participants must consider how they can work together, bringing in a variety of actors, in order to make a difference.

The speakers then noted that the 2030 agenda for sustainable development calls for improved quality of life and environmental preservation. There is a need for new infrastructure and renovation of existing structures, but a significant amount of greenhouse gas emissions comes from construction. The world needs more sustainable building practices and materials, and efforts to promote energy efficiency. The speakers presented the concept of a roadmap that prioritizes sustainable practices, and education initiatives, and other areas. A mission critical initiative is essential for preserving human species and we must advocate such change based on science and technology.

Discussion

The participants then held group discussions. The participants considering three topics, based on case studies from different countries. Firstly, information dissemination can be difficult, such as on the benefits of using wood over steel in construction, especially considering the different perspectives of different cultures. Education for a wide population will be important in resolving this. Secondly, although some countries prefer the use of cheaper aid, sometimes the solutions or technologies are not adapted to the local situation. Therefore, it will be important to provide tailored measures, as well as education and training so that local people can incorporate them. Thirdly, different countries will need to consider whether top-down approaches or bottom-up approaches are better suited to their situations, depending on the situation.

The participants then discussed the impact of climate change on food security and the roles governments can play. Particularly focusing on natural disasters such as flooding and drought, countries will need to introduce technologies and solutions suited to their local situations. The participants also considered supply chain disruptions, and the need to introduce innovative technologies that can respond to these disruptions. The participants emphasized the importance of maximizing technology innovations and collaborations between countries.

Next, the participants considered the importance of learning from past knowledge, such as the agriculture and farming methods used by ancient cultures, and how farmers can benefit from sustainable agricultural practices. However, as many sustainable solutions can

be costly, the participants considered that these practices need to be made feasible for all countries and societies. Technology and science will play a role in providing new cost-effective solutions. Collaboration will be essential to distributing these solutions between different countries.

Lastly, the participants discussed the importance of inclusivity in addressing climate risks. Effective communication on climate risks will be essential, and disaster responses must involve all stakeholders. For example, honestly communicating about such issues as the tradeoffs between different energy sources, without political rhetoric, will build better trust leading to more support and cooperation from all levels of society. However, there are various issues to inclusivity, such as how often there is not a single solution to a situation. This also emphasizes the importance of education. Lastly, the participants pointed out the necessity of creating formal support networks for formal groups in disaster preparations.

Climate Risks
Adaptation to Climate Change

[Chair]

Falk, Jim, Professorial Fellow, School of Geography, Earth and Atmospheric Sciences, University of Melbourne; Emeritus Professor, School for Humanities and Social Inquiry, The University of Wollongong, Australia

[Speakers]

Damania, Richard, Chief Economist, Sustainable Development Practice Group, World Bank, U.S.A.

von Braun, Joachim, President, Pontifical Academy of Sciences, Vatican City State; Professor for Economic and Technological Change and Director, Center for Development Research (ZEF), Bonn University, Germany

Yamagiwa, Juichi, Director-General, Research Institute for Humanity and Nature (RIHN); former President, Science Council of Japan (SCJ), former President, Kyoto University, Japan

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

Opening Remarks

The chair began by introducing key observations that the issue of adaptation has historically been overshadowed by mitigation. However, it has become clear that adaptation is very important and mitigation and adaptation must be discussed together. The chair also highlighted that oceans hold 60 times more carbon than the atmosphere, and life supporting effects of the oceans are being affected by human activities and global warming. Across mitigation and adaptation processes, there is a need for governments to regulate the impact on oceans. There is also a greater need for support at local and regional levels to implement controls and anticipate and adapt to increasing impacts from ocean destabilization.

Falk, Jim

The speakers then introduced the Biosphere 2 controlled environment project being implemented by the U.S. to study the impacts of climate change. The key takeaways are that climate change is not the only issue of concern. Mitigation and adaptation must both be implemented to reduce the harmful actions of humans, and to promote societal transformation such as behavioral change. The speakers also introduced the solution of placing solar panels above crops or grazing lands to reduce the impacts of extreme weather on agricultural production, such as providing shade to avoid heat stress on plants and livestock, as well as to provide energy to local areas.

Next the speakers discussed the hydrological cycle and rainfall. Without rainfall that is predictable and adequate, economies are impacted badly. Climate change is causing more extreme rainfall events and floods, but also droughts that affect crop and food production. The traditional response from governments is to build dams and promote water storage, but this is not appropriate adaptation as the water is still scarce. There will be no adaptation without better ways to manage water and hydrological cycles, and nature-based solutions, such as promoting the use of natural forests, should be promoted.

The speakers then emphasized that mitigation, adaptation, and transformation are the key pillars to climate resilience. Global financing has done very little to support adaptation, and adaptation at the local level needs to be scaled up. Humanity needs to confront a portfolio of issues, and there are institutional initiatives that address these. One such initiative was a series of summits being implemented in various countries around the world that have identified four action areas; innovative finance systems and preparing for mitigation; transformative actions in carbon farming and bioeconomy; information systems to strengthen resiliency, and; urban transformation with biobased construction.

The speakers also considered biodiversity conservation and disaster resilience. Biodiversity is an essential element in limiting climate change, and recent studies have shown that if biodiversity falls, social functions will decline. The speakers highlighted efforts being made in Japan to address biodiversity, such as establishing national parts and using the forests in temples and universities to increase conservation. Japan has also implemented a variety of measures using indigenous knowledge to reduce the damage from flooding and rainfall with low cost, and introducing such measures to other countries around the world.

Discussion

The participants moved to group discussions, first considering the core question of how local authorities and national governments can be a team and create a sustainable partnership to address climate change. Mitigation is a global issue, but adaptation is a local problem. The world needs to start providing education to all people, starting from school levels, to teach people how adaptation measures can apply to their local communities. It will be essential to boost partnerships from different levels of communities to make sustainable solutions.

The participants also considered that it will be beneficial to establish a framework for sharing localized knowledge. The world needs tools for standardization and a standard global language that different communities can use for exchange. The participants also considered water supply issues, particularly as water available is an issue for countries in the global south. This led to discussions on the concept of property rights for nature, and determining whether private or public ownership of nature will need to be defined, in the same way it is defined for technologies. The roles of the collective versus the individual when considering climate change adaptation will also need to be defined.

The participants also considered three key words; education, decent realization, and science and policy linkage. On the subject of education, the content of education, such as what information to provide to who, must be carefully considered. On decent realization, there is a disproportionality between politicians and local governments, and many actions to address climate change are too long term. Therefore, projects need to be constrained from becoming ongoing topics, and local governments should be given more decision-making power to fit their local situations. On science and policy linkage, science at the local level needs to be promoted more, which will lead to adaptation and transformation in the future.

The participants also discussed four central themes of climate risks. The first is that adaptation inclusion is important. People will respond more readily if they are included, and if solutions are made cheaper for implementation. The second theme is the role of traditional knowledge. This knowledge should not be replaced, as it is often adapted to unique and individual ecosystems, so traditional knowledge should be connected and integrated into climate adaptations. This connected to the third theme, the need for balance. Traditional knowledge is useful, but it is important to balance that with modern developments. The fourth theme is demographics and economic considerations, which will affect how individuals and countries adapt to climate change.

Demography
Declining Population

[Chair]

Lutz, Wolfgang, Founding Director, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU); Distinguished Emeritus Research Scholar, IIASA, Austria

[Speakers]

Kaneko, Ryuichi, Professor, School of Political Science & Economics, Meiji University; former Deputy Director-General, National Institute of Population and Social Security Research, Japan

Madise, Nyovani, President, Union for African Population Studies, Ghana; Country Director (Malawi) & Director of SDGs Research, African Institute for Development Policy, Malawi

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

Ataka, Kazuto, Professor, Faculty of Environment and Information Studies, Keio University; Senior Strategist, LY Corporation, Japan

Opening Remarks

The chair first presented an overview of demography and the concept of global demographic transition, which is a universal process of death and birth rates falling from high and largely uncontrolled levels to low levels, that all societies go through but with different timing. Fertility rates and reproductive behavior are more deeply embedded in the cultural norms of societies and thus change more slowly, driven by improving female education and general modernization. Different countries are currently at different levels of this universal transition with some seeing stagnating or declining populations, and others such as in Africa still growing. Multi-dimensional demography considers structures that go beyond age and sex, such as labor force and education. It will be essential to consider science and technology influence in responding to population decline.

Lutz, Wolfgang

The speakers considered population trends through history, and how the current decline may be more permanent and comes with

population aging. The primary cause of low fertility is the increasing sense of burden of raising children in modern societies, both on mothers and fathers. Governments must make efforts to reduce the burden on parents and make environments more child friendly. In modern society, where the framework for cooperative breeding, humanity's original reproductive strategy, has broken down, the government must take on the role of a participant and share responsibility for raising children. It will also be important to consider how to maintain societal productivity through qualitative improvements. If utilized effectively, increasing human capital with technology innovations can be used to sustain societal productivity.

The speakers then focused on Africa, where the fertility rate is double the rest of the world. High fertility in Africa is a result of still high rates of child mortality, low status of women, poor access to and low quality of education especially for girls, and low levels of economic development. High fertility affects development because the per capita spending on things like health and education is low as more and more babies are born. Rapid population growth also affects the environment as there is a demand for more natural resources such as water and land to grow food for growing populations. Some countries in Africa are addressing the high fertility rates through measures such as reducing child marriages and adolescent pregnancies. Keeping girls in school for longer is a powerful measure that has other benefits such as better child survival rates and women's economic empowerment. Further economic and technological transformations will be needed to strengthen education, digital and health systems, particularly once Africa begins to face the issue of aging societies. Achieving gender equality is important for addressing the challenges of both high and very low fertility.

Next the speakers introduced the situations in Singapore. Young Singaporeans want to have children, but also need to balance other responsibilities and aspirations. One response from the government has been to encourage childcare leave by increasing the number of weeks parents can take for childcare. Singapore also has about 30% non-residents in a total population of 5.9 million in 2023, which contributed to the sustained population growth in the last three decades. Singapore looks to develop a sustainable population with three objectives; build strong and cohesive societies while preserving the multi-racial and religious nature of Singapore; support a dynamic and vibrant economy by creating good jobs and opportunities for the resident population, complemented by a migrant workforce, and; providing high quality living environment for all.

Finally, the speakers examined the structural causes of population decline (improved child survival rates, increased child-rearing costs, higher education levels, delayed marriages, and career focus) and introduced the challenge of “reverse scalability” - maintaining efficient functioning in shrinking environments. Emphasis was placed on the need to adapt businesses and public services, reimagine social security and infrastructure, and leverage AI/IoT/robotics for efficient service delivery. The speakers proposed accepting population decline as a long-term trend, focusing on efficiency and sustainability rather than growth, and urged the audience to embrace technological innovation and social adaptability. The talk concluded by framing this demographic shift as an opportunity to create more sustainable, efficient, and resilient societies for future generations.

Discussion

Following the opening remarks, the participants held a group discussion, beginning with the question of the intention of mothers in terms of how many children they wish to have. Increased education has also been shown to lead to lower fertility in countries such as Africa. The participants also compared countries such as Estonia, where the fertility rate decreased but saw increased paternity leave and salaries, and Bulgaria, where there is both low fertility and high migration thus further reducing the population. On the subject of immigration, the participants agreed that countries will need to ensure tolerance when welcoming immigrants to prevent social issues.

The participants also discussed the rising costs of children and childcare. Related issues include rising housing costs, decreasing salaries, anxiety over future expenses, school expenses, and that all of these are not one-off expenses. Current governments are providing incentives, but these payments are not sufficient. Addressing the costs of childcare would in turn lead to addressing the issue of fertility, by adapting to the situation.

The participants then considered how technology has been affecting the population in different ways, ranging from technologies for assisted reproduction to social media influences. The participants also discussed political failures, such as short-term incentives, and the question of whether it is better to attempt to mitigate the issue. Technology will also be critical for addressing productivity amid aging societies. This created a dilemma of whether technology will replace jobs, and keep people in labor for longer periods. Gender and other inequalities will also affect decision making.

The participants also compared the incentives required to encourage immigration, including government policies to reduce social disparities, establishing public housing, and subsidies to improve fertility. There are new trends in multicultural society, such as intercultural marriages and difficulties due to lack of opportunities in more affluent countries. The participants also noted the importance of measures to incentivize fertility, such as creating child sensitive demographics.

Life Sciences
AI for Health

[Chair]

Zerhouni, Elias Adam, Professor Emeritus, Radiology and biomedical engineering, Johns Hopkins University; former Director, National Institutes of Health (NIH), U.S.A.

[Speakers]

Bentwich, Isaac, Founder and CEO, Quris-AI, Israel

Bielecki, Michel, Co-founder & CEO, illumicell AI, U.S.A.; Researcher, Epidemiology Biostatistics and Prevention Institute, University of Zurich, Switzerland

Fire, Andrew Zachary, Professor, Departments of Pathology and Genetics, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2006 (Physiology or Medicine)]

Hahn, Maria, CEO and Founder, Nutrix AG, Switzerland

Hamaguchi, Michinari, Director General, Strategic Center of Biomedical Advanced Vaccine Research and Development for Preparedness and Response (SCARDA), Japan Agency for Medical Research and Development (AMED); Counsellor to the President, Japan Science and Technology Agency (JST), Japan

Lovis, Christian, Director medical information sciences, Division of Medical Information Sciences, Diagnostic department, University Hospitals of Geneva (HUG); Professor and Director, "Genomics and digital health" track of the doctoral school in Life Sciences, University of Geneva, Switzerland

Tian, Mei, Executive President, Human Phenome Institute, Fudan University, China

Zerhouni, Elias Adam

Opening Remarks

The chair opened by noting that health is one of the most critical areas of application for AI. The amount of gross domestic product dedicated to healthcare continues to grow and AI has the potential to improve the efficiency and effectiveness of all aspects of healthcare systems, from R&D to disease prevention. AI has enabled the management of huge amounts of complex data, the prediction of the functionality of molecules, and computer-aided diagnostics, among other benefits. At the same time, however, it has also raised

ethical and privacy issues related to patients, and could also be used for negative purposes that hamper health.

The speakers then spoke about efforts to combine advanced biology, through miniaturized human organs in microfluidic chips, to generate data for training AI to improve drug development and help consumers make safer drug choices. Large language models (LLMs) have impacted people's lives in amazing ways. However, an even greater wave of change is coming. This will come from foundational models trained on data that is as close as possible to the biology itself, whereas LLMs actually deal with text about the biology.

The speakers also noted that rapid advances in AI offer huge opportunities in healthcare, such as transitioning the field from traditional intuition-based practices to precise data-driven science. They could also improve healthcare access, for example by making a DoctorGPT a primary care practitioner. Still, the rise of AI should augment the role of physicians, not replace them. However, dialogue, education, and collaboration are needed to foster acceptance of such AI positions by society, which raise difficult societal questions.

Next, the speakers considered how anecdotal observation and innovation must complement AI use in healthcare. AI relies on and learns from data such as patient diagnoses and outcomes. However, these data are only updated up to a certain point in the past, creating

a lag. The anecdotal observations of physicians are critical for teaching AI to deal with the changing world. Physicians and researchers must also innovate to deal with new issues or situations, and that again goes beyond what AI can learn from existing data.

Another topic was the massive opportunity that AI offers to increase accessibility to healthcare and improve its effectiveness, especially given the high and growing cost of healthcare. For example, AI can extract information from different types of data, overcoming previous complicated data interoperability issues. AI can also provide faster and personalized care. Nevertheless, AI will never replace medical doctors, but it can augment medical teams. These teams should be multidisciplinary, and collaboration will be critical for obtaining the data needed for precision and personalized medicine.

Then, the speakers turned to the application of AI in basic research, particularly in vaccine development. For example, AlphaFold can predict the 3D structure of bio-antigens, which has been a boon for vaccine development, in terms of precise design of antigens. Furthermore, AI can support the analysis of Big Data, particularly for phase 2 and phase 3 clinical trials of vaccines. There are, however, also dark sides to AI. It can be used to magnify disinformation and misinformation, such as in anti-vaccine movements. There is also a need to ensure data security. We must continue to take the initiative to develop human-centered AI for the benefit of human society.

In addition, the speakers highlighted that AI involves both data and knowledge, emphasizing the integration of symbolic reasoning with data-driven approaches. They cautioned against over-reliance on LLMs trained on potentially unreproducible studies and stressed the importance of human research and human nature in scientific breakthroughs. They also proposed refocusing AI development on administrative tasks rather than replacing human diagnostic capabilities. The value of task-specific AI models and the need to improve AI models' learning capacity and adaptability were also noted.

The speakers also discussed an ongoing Chinese cohort study that has calculated all phenotypes in the cohort and seeks to integrate them with multiple "omics" data. AI-assisted technology has significantly improved the efficiency of data analysis, reducing the processing time from weeks to hours. AI also holds further potential, including enabling better understanding of the mechanics of organ crosstalk, supporting precision medicine or more precise medicine, and facilitating the discovery of new treatment targets and biomarkers.

Discussion

Following the opening remarks, the participants held a group discussion. They first spoke about how AI can drive novel forms of scientific innovation. At the same time, they recognized the importance of the human mind and creativity for innovation, cautioning that excessive use of AI could limit innovation. The participants also noted the need to narrow down the top priorities that AI should be applied to, rather than applying it to the whole healthcare system at once.

Next, the participants touched on the need to standardize data inventories across the world, such as biobanks, noting that the quality of AI algorithms depends on the quality of data and data collection. They also noted the need to build on governance frameworks, while debating whether regulation helps or hinders the collection of data and the deployment of AI applications.

The dark sides of AI in healthcare were also discussed, including concerns about how quickly fear about use of AI could spread, as well as data privacy issues and trust. Participants noted that data ownership and the right to opt out increases trust. They also recognized the need to understand cases where the use of AI works well and those where it works less reliably. Furthermore, they pointed out that creativity and critical thinking in AI education are important for ensuring appropriate use, rather than misuse, of AI.

The participants agreed that AI should assist not replace medical practitioners, emphasizing the importance of human skill and decision-making, and noted that AI being a tool rather than a decision-maker enhances trust. Furthermore, they stressed the need to ensure that increased use of AI does not deteriorate the training or knowledge of physicians.

Access to healthcare was also emphasized. It was pointed out that even if AI can correctly diagnose a patient, this is of no use if the patient cannot then access the requisite treatment.

Life Sciences
Breakthrough in Biotechnology

[Chair]

Watt, Fiona, Director, European Molecular Biology Organization (EMBO)

[Speakers]

Ogawa, Miho, CTO, OrganTech Inc., Japan

Donati, Daria, Chief Scientific Officer, Genomic Medicine, Cytiva, Sweden

Flores Bueso, Yensi, Co-Chair, Global Young Academy, Germany; Marie Curie Postdoctoral Fellow, Institute for Protein Design, Cancer Research, University College Cork (UCC), Ireland; University of Washington, U.S.A.

Launey, Thomas, Chief Researcher of Biotechnology, Advanced Technology Research Council (ATRC); Chief Researcher and VP Molecular Biotech & Genomics, Biotechnology Research Center, Technology Innovation Institute, Abu Dhabi, U.A.E.

Quake, Steve, Head of Science, Chan Zuckerberg Initiative; Lee Otterson Professor of Bioengineering and Applied Physics, Stanford University, U.S.A.

Kobilka, Brian, Professor, Molecular and Cellular Physiology and Medicine, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2012 (Chemistry)]

Opening Remarks

The chair began the session by noting that advances in biotechnology have undoubtedly transformed society, improving human, animal, and plant health, and bringing about economic benefits, and will surely continue to do so. However, there are also many challenges, such as ensuring equal access to biotechnological advances, research and development not being equally supported in different countries, the difficulty of harmonizing national regulatory systems, and helping academic scientists to have realistic expectations of their research's commercial potential and to chart a clear route to commercialization.

Watt, Fiona

Next, the speakers took up the challenges of full-scale implementation of biotechnological advances, looking at the example of a novel 3D cell manipulation method that has enabled the recreation of various organs, such as teeth, hair, and saliva glands. The speakers noted disparities in access to cutting-edge treatments and the need for international collaboration and collaboration among government, industry, and academia to ensure that the benefits can be enjoyed widely by society. They also noted obstacles to commercialization, such as differing regulations among countries, and the need for greater regulatory harmonization.

The speakers then considered the role of manufacturing in translating emerging technologies into accessible treatments. Agile, flexible, and scalable manufacturing strategies are key to producing complex genomic medicines. Advances in manufacturing technologies such as single-use manufacturing have enabled greater flexibility and reduced time and cost. The integration of AI and digital technologies has also enhanced predictability and enhanced processes. Innovations in drug discovery, preclinical testing, and clinical trial design are also reducing development times and costs. Regulatory authorities are now exploring new review and approval models, to enable approval of genomic medicines.

Following this, the speakers noted bottlenecks in global healthcare, such as diverse healthcare systems and the lack of correct incentives, and advocated placing social benefits at the core of global healthcare and embracing collaboration to promote sustainable

development. They also discussed how innovative tools could help democratize advances in biotechnology, such as de-risking projects and streamlining research using synthetic biology and computational design tools. There is also a need to empower underrepresented groups and AI can bridge such gaps.

In addition, the speakers discussed the transformative force of machine-learning and AI in biotechnology research. Machine-learning and AI can navigate layers of complexity involved in biotechnology that can surpass human comprehension, enabling the creation of actionable knowledge and products. Biotechnology itself is changing as a result and there will be a need to collect data more systematically and efficiently going forward, including through increased automation. There are also challenges such as the high cost of entry posed by access to good datasets, and the increasingly heavy energy consumption from machine-learning.

The importance of basic science and interdisciplinary science to making transformational discoveries were also discussed, with a particular focus on the efforts of the Chan Zuckerberg Initiative (CZI). One notable example is CZI's use of computational tools to build models of different cell types with the aim of using AI technology to pave the way for a future where scientists can instantiate "virtual cells" for any and all cell types across tissues, individuals or conditions to accelerate research. It has also developed software tools to enable open access to the related data.

The speakers also discussed strategies for developing drugs targeting G protein coupled receptors (GPCRs). GPCRs control many aspects of physiology, making them great potential therapeutic targets. However, advances in drug discovery to target GPCRs have been disappointing, due to problems such as complex signaling and difficulty finding path-selective drugs, and the presence of polymorphisms. However, other scientific advances offer potential reasons for optimism, such as advances in single-electron microscopy that have enabled the use of structural biology to aid drug development, as well as in silico screening of drugs.

Discussion

The participants then held a discussion. First, they looked at ways to achieve next-generation manufacturing such as remote and continuous manufacturing. They noted the potential of greater utilization of biological tools, facilitated by advances in biology, and greater uptake of digitalization and AI, which has been somewhat slow due to issues such as data

ownership. They also spoke about the bottleneck posed by quality control in the development of cell therapies, and the potential of advances in sensor technology and AI to enable better monitoring of quality at every stage of the manufacturing process.

Another theme discussed was equitable access to the outcomes of advances in biotechnology. Sometimes the hindrance can be mainly due to logistics, and participants noted the need to further develop global supply chains. The value of international collaboration and sharing of knowledge to develop the capacity of countries with fewer resources was also noted.

As a related point, the participants discussed the value of early and free sharing of data. However, it was also pointed out that there may be many overlapping machine-learning efforts occurring on the same datasets, and that greater collaboration to reduce such overlap could mitigate excessive consumption of energy.

In addition, the participants discussed developments in precision medicine. They noted that, currently, the most feasible application for gene therapy is for single-gene-derived diseases. However, the problem with many such diseases is the very small group of patients.

That creates not only cost issues, but also difficulty conducting clinical trials. This is an issue that regulatory authorities are beginning to think about as well.

The participants then turned to government-related aspects of biotechnology. They emphasized the importance of harmonizing risk assessment across countries and ensuring regulations do not hinder international collaboration and data-sharing. Governments could also play a role in establishing international quality standards for data collection and dataset generation. The importance of supportive environments and funding mechanisms to enable the translation of basic research into biotech startups was also mentioned.

In addition, the participants discussed the possibility of developing digital twins in biotechnology, noting ongoing research and significant interest in this area. Other promising developments in biotechnology research, such as cellular recorders, advanced cellular therapies, and automated high-throughput data generation were also discussed.

Life Sciences
Patient Advocacy

[Chair]

McKinnell, Henry A., Chairman, American and Canadian Associates STS Forum; former Chairman/CEO, Pfizer, U.S.A.

[Speakers]

Cardone, Antonella, CEO, Cancer Patients Europe, Belgium

Collins, Mary, Blizard Institute Director, Professor of Virology, Queen Mary University of London, U.K.

Garcia-Gonzalez, Pat, Chief Executive Officer, The Max Foundation, U.S.A.

Kurth, Ann, President, New York Academy of Medicine; Faculty, Yale University School of Nursing, U.S.A.

Terry, Sharon, President and Chief Executive Officer, Genetic Alliance, U.S.A.; President, EspeRare, Switzerland

Opening Remarks

The chair started by pointing out that while there might seem to only be lights to patient advocacy, if one thinks about it carefully, some shadows could surely also be found. First, to illustrate the lights of patient advocacy, he mentioned examples of clinical studies that asked patients what they considered to be the benefits of certain drugs that a pharmaceutical company was developing. Their answers yielded perspectives and insights that the company would not have realized on its own. Then, to illustrate the shadows, the chair shared anecdotes showing how a person or an advocacy group intending to speak on behalf of a patient could instead end up pushing their own views or advocating for the wrong thing.

McKinnell, Henry A.

Following this, the speakers discussed the role of patient associations. The speakers highlighted the importance of representation and governance to the work of such associations, as well as the need for them to maintain

their independence and therefore their trustworthiness. The speakers also discussed how patient associations can not only promote patient advocacy in research and treatment, but also promote advances in research and patient outcomes by supporting cross-border clinical trials and making evidence from research more accessible and comprehensible to policymakers.

Next, the speakers discussed the importance of involving local communities in research, which improves its quality and relevance. They focused on examples from East London, looking first at Genes & Health, a community-based genetics study that aims to improve health among East Londoners of Pakistani and Bangladeshi heritage by analyzing their genes and health. They also discussed a new tuberculosis research project that both addresses a need for tuberculosis care in East London, and also provides an opportunity to research improved diagnostics.

The speakers then looked at some of the shadows of patient advocacy. They highlighted the higher cancer mortality rate in lower-income countries and the issue of unequal access to treatments, as well as the need to ensure proper representation of these populations by patient advocates and advocacy organizations. There is also insufficient opportunity for input from patients and advocacy groups in important decisions about which medical technologies to develop, with consultation often occurring after the fact. There may be a need to reconfigure incentives in medical research to ensure greater benefits for everyone.

The importance of participatory research and patient and public involvement was also discussed. There are many examples of citizen and advocate involvement in scientific advancements, and research efforts centered on community engagement and co-learning with residents can lead to the development of research-informed policies, more relevant health solutions, and increased trust. However, there are also systemic barriers to participatory research and collaboration, including funding structures and institutional norms. Participatory research also presupposes trust, which is often in short supply among structurally disadvantaged populations, as well as scientific literacy. These challenges must be addressed with greater science, technology, engineering, and mathematics education and a more diverse scientific workforce.

Lastly, the speakers stressed the importance of advocacy and engagement, and noted the need for patients and advocacy organizations to not only participate in research but to drive it. They also considered some of the shadows of advocacy organizations, including the

professionalization of some to the point where the organization is more important than the people they are supposed to advocate for. Another challenge is that advocacy organizations are often asked to provide well-characterized cohorts, but they have no regular sources of funding. The point was also made that, rather than asking for trust, advocacy organizations and industry should do more to demonstrate how they are trustworthy.

Discussion

Following the opening remarks, the participants engaged in a group discussion. They began by discussing how advocacy organizations assess potential interventions and recognizing the importance of avoiding bias. They also noted the need to secure funding while maintaining independence to avoid being beholden to a particular company or government.

Next, the participants discussed the importance of representation and maintaining a diversity of opinions from patients. This includes helping certain patient groups that are not used to having a voice to embrace theirs. The participants also agreed on the value of engaging in direct dialogues with patients and hearing from them about their experiences and challenges, which can yield insights that clinicians or researchers do not expect. One way to facilitate the sharing of patient perspectives with clinicians and researchers, as well as with other patients, could be through public platforms.

In addition, it was noted that patient advocacy and feedback can help shape the allocation of research efforts to better meet patient needs. Research can be enriched by patient experience and patient feedback aids not only drug development but can also help with marketing a drug.

The cases of countries that do not have established advocacy foundations was also taken up. The participants discussed different forms of potential support for families, depending on their goals, such as holding bootcamps to walk families through the necessary steps for becoming an independent entity or foundation.

Finally, the participants discussed examples of advocacy groups reaching out to medical schools and engaging with medical students. They also touched on the role of patient navigators, who help patients navigate the potential complexity of the medical system.

Innovative Engineering
Revolutionary Materials and Devices

[Chair]

Curioni, Alessandro, IBM Fellow, Vice President, Europe & Africa and Director, IBM Research - Zurich, IBM Research Europe, Switzerland

[Speakers]

Sarrao, John, Director, SLAC National Accelerator Laboratory, U.S.A.

Hono, Kazuhiro, President, National Institute for Materials Science (NIMS), Japan

Maheshwari, Dinesh, Chief Technical Advisor, Groq Inc, U.S.A.

Shekhar Sharma, Chandra, Co-Chair, Global Young Academy, Germany; Dean (Research), Indian Institute of Technology Hyderabad, India

Pasquali, Matteo, A.J. Hartsook Professor, Chemical and Biomolecular Engineering Professor, Chemistry and Materials Science and Nanoengineering Director, Carbon Hub, Rice University; Chief Scientific Officer, DexMat, Inc., U.S.A.

Yoshino, Akira, Honorary Fellow, Asahi Kasei Corporation, Japan [Nobel Laureate 2019 (Chemistry)]

Opening Remarks

The chair opened the session by emphasizing the critical role of materials and their integration into devices for societal development and solving significant problems like climate change. Faster material development is needed while considering sustainability, circular economy principles, and geopolitical issues. The importance of utilizing advanced experimental techniques, AI, and computing to integrate sustainability into the full design and integration chain was highlighted.

Curioni, Alessandro

The speakers then discussed the balance between discovery-driven research and technology-driven needs in materials science. The role of serendipitous exploration in materials discovery was emphasized, with examples from superconductor research. Advanced light sources enable unprecedented materials characterization at fundamental temporal and spatial scales. Partnerships with industry are also critical for accelerating progress in materials science.

The discussion then turned to the critical role of materials science in addressing global issues such as sustainability, energy efficiency, and resource scarcity. Developing materials for carbon neutrality, low-power semiconductor devices, and neuromorphic devices is an important challenge. Environmentally friendly materials, circular economy principles, and addressing supply chain vulnerabilities due to geopolitical tensions are necessary. In addition, attracting young talent globally is essential to sustain the development of material technology.

The speakers then touched on the topic of the compute intensity and energy requirements of machine learning systems. New compute paradigms and advanced materials need to be developed. The building blocks of compute systems include compute logic, memory, power delivery, and off-chip computation subsystems. New materials that can be stacked on silicon wafers are required to enable higher density memory, improved power delivery, and optical communication capabilities, and these devices will need to be cost-effective to manufacture.

The speakers next emphasized the importance of developing new and advanced materials to address global challenges such as climate change. Various types of materials and their applications in renewable energy, healthcare, and sustainable infrastructure were discussed. Sustainable and scalable methods in materials development are necessary, with a focus on fundamental understanding, advanced characterization techniques, and the use of AI and computational modeling. Recycling and reusing materials for sustainable development is another key.

Following this, the relationship between energy systems, carbon dioxide generation, and materials production was explored. The competition for resources among proposed climate change solutions and the higher material intensity of renewable energy systems compared to traditional ones were highlighted. Carbon materials based on carbon nanotubes were introduced as potential alternatives to traditional construction materials, as they can be produced from carbon feedstocks without generating carbon dioxide. Challenges and opportunities in developing these new materials and their potential impact on the energy transition were discussed.

Finally, the speakers presented on the application of AI technology in battery development. AI is being used to develop solid electrolytes, predict battery life cycles, and detect defective products in manufacturing. It can classify relationships between molecular structure and ionic conductivity in solid electrolytes, and predict long-term battery life from limited cycle data. Challenges in AI implementation include collecting high-quality data and verifying AI judgments. New social systems are needed to address these issues.

Discussion

The discussion began with a question on whether it was more important to focus on optimizing existing materials and processes or designing new ones. In the context of computation, participants discussed the potential of building upon existing silicon infrastructure while developing new stackable materials for additional functionality. More broadly, they also advocated for a balanced approach, improving existing materials while investing in new ones. It was noted that it is necessary to switch from traditional materials to more sustainable alternatives, citing examples from energy and transportation sectors.

The conversation then addressed sustainability in the materials discovery cycle. Some participants suggested looking to nature for inspiration in developing sustainable materials and processes. The importance of bio-inspiration and nature-inspired materials was emphasized. The discussion also gave mention to the role of public and private institutions in research and development.

The participants weighed the benefits and challenges of a potential paradigm shift away from incrementally improving existing materials like steel and aluminum, towards developing entirely new materials with dramatically reduced resource footprints and CO_2 emissions.

The discussion then turned to the challenges of data sharing and collaboration in AI-driven materials research. A question was raised about changing societal rules to enable better use of data for AI applications in healthcare. While challenging, there is an example within cancer research where data sharing has been successful. User facilities could serve as neutral grounds for pre-competitive data sharing among industrial partners.

Participants also explored the changing dynamics between public and private sector research funding and the need for new collaboration models. The importance of balancing global cooperation on issues like climate change with national strategic interests was noted. The discussion touched on the potential of quantum computing to accelerate materials discovery, with notable progress in the potential of quantum materials simulations with recent advances.

The session concluded with reflections on the role of AI and computational modeling in materials science. While some participants expressed optimism about AI's potential to uncover new materials and properties, others cautioned that existing physical understanding should not be discarded. Simulations and modeling have already suggested possibilities for materials, with recent experimental confirmation of a theorized single-atom covalent bond as an example of how computational approaches can drive new discoveries.

Innovative Engineering
Quantum Science and Technologies

[Chair]

Meyerson, Bernard S., IBM Fellow, Chief Innovation Officer Emeritus, IBM Research, IBM Corporation; CEO, 4IRAdvisors, U.S.A.

[Speakers]

Ali, Mazhar, Professor, Department of Quantum Nanoscience of the Faculty of Applied Sciences, Delft University of Technology, Netherlands; Chief Scientist, Material Mind, U.S.A.

Gutfreund, Hanoch, Professor Emeritus; former President, Physics, The Hebrew University of Jerusalem; Israel

Hewett, JoAnne, Laboratory Director, Brookhaven National Laboratory (BNL), U.S.A.

Kranzlmüller, Dieter, University professor, Ludwig-Maximilians-Universität München (LMU); Director, Leibniz Supercomputing Centre (LRZ), Germany

Thom, Murray, Vice President of Quantum Technology Evangelism, D-Wave Systems, Canada

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

Opening Remarks

The chair opened the session by reflecting on the remarkable progress in computing technology. He traced the rapid evolution to modern supercomputers, and emphasized the tremendous potential of quantum computing and a million-fold improvement in computational power. Further advancement within quantum computing could revolutionize various fields, ranging from drug design to protein folding. The concentration of diverse expertise in this session was highlighted as an opportunity to come up with ideas which could make a substantial impact on society.

Meyerson, Bernard S.

The speakers then expanded the discussion to quantum science and technology broadly. Quantum sensing was highlighted through an analogy of single photon detectors, and the speakers explained quantum transduction and its role in converting information between

different forms. They envisioned a fabric of quantum sensors, computing, and transduction that could revolutionize the human experience. It is important to build a comprehensive ecosystem involving governments, industry, and private foundations. Education was stressed as crucial, including bringing quantum studies to students earlier than the doctoral or post-doctoral levels. Finally, they urged policymakers to start thinking now about how to ensure access to quantum technologies in the future for all members of society, in analogy to discussions and efforts surrounding access to AI today.

Next, historical context for quantum theory was provided. The speakers traced the development from early pioneers like Max Planck and Albert Einstein to the current "second quantum revolution." The shift from the Copenhagen interpretation to the concepts of entanglement and non-locality was discussed. The speakers also highlighted contributions of theoretical visionaries like John Bell and experimentalists such as Alain Aspect. David Bohm's role in the field was touched upon, with mention of upcoming publications that may shed new light on his contributions.

The speakers then discussed about the National Quantum Initiative in the United States. The initiative has five research centers hosted at national laboratories, each with a unique focus, and specific examples of accomplishments include quantum foundries and improvements in superconducting qubit performance. The initiative's role in advancing basic research,

technology transfer, and workforce development was emphasized, noting the engagement of over 1,500 collaborators and 200 companies.

Following this, the integration of quantum computing was contemplated from the perspective of computer science education and research. The speakers described the installation of a country's first superconducting quantum computer in a data center and outlined plans for future expansion to 1,000 qubits. Emphasis was placed on the importance of combining traditional computing with quantum computing, with an example of a program successfully executed using both systems. To continue making progress in quantum computing, researchers must tackle remaining challenges in both physics and computer science.

In terms of practical applications of quantum computing, the speakers explained about different models of quantum computers, focusing on quantum annealing and its applications in optimization problems. Achievements include a computational supremacy demonstration and commercial applications in employee scheduling and signal optimization. It is important to have user-friendly interfaces, and there is substantial potential for quantum computing to greatly reduce power consumption in certain calculations, particularly in AI applications.

Lastly, the speakers discussed the quantum revolution in metrology and its global impact on measurement standards. At a 2018 conference, countries unanimously agreed to adopt quantum-based units of measurement. The speakers noted challenges in quantum computing research, and suggested a cautious approach to avoid excessive competition between nations. The speakers advocated for a more collaborative approach to advancing quantum technologies, drawing parallels to the cooperation seen in quantum metrology. Despite geopolitical tensions that exist in the modern world, the speakers expressed hope for international cooperation in quantum computing research.

Discussion

The discussion began with participants acknowledging the current state of quantum computing technology as clunky, large, and noisy. Despite challenges in using these systems for real applications, significant progress has been made in controlling quantum systems at scale. The discussion also touched on the potential for cloud-based solutions and the significance of scalability. The importance of collaboration between different fields such as physics, electrical engineering, and computer science was also highlighted.

Regarding the philosophical question of why there are currently few existing quantum algorithms, the participants underscored the challenges of thinking in quantum terms, drawing parallels to the early development of classical computers. The potential future applications of quantum computing were considered, with the possibility that unforeseen uses may emerge, similar to how classical computers evolved beyond initial expectations.

The participants then commented on workforce development, emphasizing the need to engage all generations, not just young or early career individuals. The group next explored areas where quantum computing capabilities have already exceeded classical systems, such as protein folding research and dark matter searches. The significance of open research and international collaboration in advancing quantum science were emphasized.

Next, the participants discussed the high level of expertise required in various domains of quantum technologies, noting the need for skill in computer science. The discussion touched on international cooperation, drawing comparisons to space exploration and fusion research. Regarding societal and environmental impacts of quantum technologies, the participants suggested that it was too early to make definitive statements.

The participants addressed funding disparities between countries and the potential widening of technological gaps. Education was highlighted as a crucial factor in addressing these disparities.

In conclusion, key potential advantages of quantum computing were mentioned: increased speed, the ability to solve previously impossible problems, and energy savings. The discussion emphasized the need for proactive policy development and regulation to address potential security concerns while also recognizing the positive potential of quantum computing.

Innovative Engineering
Green Technologies

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

[Speakers]
Godrej, Nadir B., Chairman and Managing Director, Godrej Industries Limited; Chairman, Godrej Agrovet Ltd, India
Kishimoto, Kikuo, Executive Director, Technology and Innovation Strategy Center, New Energy and Industrial Technology Development Organization (NEDO), Japan
Mu, Rongping, Professor, Institutes of Science and Development, Chinese Academy of Sciences (CAS); China
Papič, Igor, Minister, Ministry of Higher Education, Science and Innovation, Slovenia

Opening Remarks

The chair opened the session by highlighting technological advancements in climate change mitigation since 2012, including progress in wind and solar power generation, electric vehicle (EV) ranges, and grid storage capabilities. Despite these improvements, greenhouse gas emissions continue to rise, with a 1.1% increase in the past year. Globally, about 37.5 billion tons of carbon were put into the atmosphere, roughly 25% higher than 2012 levels. The chair emphasized the importance of addressing deployment barriers, such as land rights issues and grid modernization challenges. Key discussion points also included strategies for expanding green energy deployment, the potential role of AI in climate solutions, and the importance of government leaders understanding the urgency of climate science.


Isaacs, Eric D.

Next, the speakers addressed the critical nature of climate change as a crisis. They noted technology's role in making green energy more affordable, with wind and solar energy production exceeding projections. Energy efficiency

was highlighted as a cost-effective path to carbon neutrality. India's progress towards meeting carbon goals while balancing coal expansion was discussed, emphasizing the need for global fairness in emissions reduction. The potential of various technologies, including modular nuclear power, biomass energy, and green hydrogen, was explored.

The discussion then outlined Japan's green transformation policies and the supporting role of technological organizations. A fund providing continuous support for carbon neutrality initiatives through 2030 was described. An "economy of natural coexistence" concept was introduced, aiming to achieve carbon neutrality, circular economy, and natural positive equality. Many efforts are underway in developing renewable energy technologies, supporting large-scale projects in 20 technology fields, and promoting international cooperation initiatives.

As for China's journey towards implementing sustainable development strategies, the speakers traced the evolution from conceptual acceptance in the 1990s to concrete action plans and investments since 2012. Three key points for future green technology development were emphasized: defining green technology within sustainable development principles, building enterprise capacity, and establishing effective collaboration mechanisms. It is vital to select technologies that align with sustainable development principles.

Finally, the discussion touched upon implementing large-scale demonstration projects for smart grids and hydrogen technologies. Slovenia's hydrogen project involves 18 partners and aims to integrate renewable energy sources with a focus on mobility, industrial applications, and seasonal energy storage. It is imperative to address legal, economic, and sociological aspects alongside technological development. This also requires interdisciplinary collaboration and user acceptance in introducing new technologies. Looking forward, the Slovenian government recognizes the importance of large-scale demonstrations for developing engineering expertise and operating new energy systems.

Discussion

The discussion began by exploring the barriers to achieving green energy, noting that while technological advancements have made solar panels cheaper and easier to install, challenges remain in transportation, storage, and grid infrastructure. The participants noted that social and political aspects, rather than technological ones, are the main obstacles towards further progress, and they emphasized the need for citizen education on the importance of green energy and lobbying politicians to create supportive policies.

In terms of the situation in India, numerous green initiatives have been profitable for businesses thanks to their resultant cost savings. Corporate social responsibility mandates, regulations, and taxes have driven adoption and led to great progress, though sectors like steel and cement still face difficulties. The participants highlighted the potential of biofuels and biomass fuel generation in agriculture, along with the importance of data and internal carbon pricing for driving complex technologies and factoring into water price decisions.

The participants broadened the consideration of green technology to include not just clean or renewable, but also mitigation and adaptation technology. Countries have varying levels of sustainability awareness and support, and therefore developed countries can be a helpful support for developing countries. A collaborative approach across governments, public, and private sectors was recommended, alongside the need to quantify risks and returns for green investments. Some participants observed rapid advancements in green building and sustainable agriculture, highlighting the breadth of sectors that are affected by green technology.

The fundamental question of how to define green technology itself, as well as the meaning of adoption scales was discussed. Energy efficiency, pollution reduction, and recyclability can also be considered aspects of green technology. On the other hand, barriers like

business cases, lack of incentives, and regulatory challenges were highlighted. To overcome some of these, it may be necessary to implement carbon taxes and address export-related emissions. Also, the uneven global penetration of EVs, and lagging progress in agriculture and heavy industry illustrate the need for further efforts to reach scale.

The participants proceeded to point out the importance of communicating time scales of research and development to politicians and the public. Highlighting successful cases is one key to justifying long-term decisions for investors. Integrating business models, technologies, and legal considerations is also essential, along with making green options more economically attractive. Such economic pressure may be necessary for success, as societal pressure alone is insufficient. Finally, the group underscored the importance of providing short-term benefits to drive change, attracting students to engineering, and the need for diverse expert consultation in policymaking.

Cooperation in S&T
Science and Technology Diplomacy

[Chair]

Parikh, Sudip S., Chief Executive Officer, American Association for the Advancement of Science (AAAS), U.S.A

[Speakers]

Bekele-Thomas, Nardos, Chief Executive Officer, African Union Development Agency (AUDA-NEPAD)

Smith, Dave, National Technology Adviser, Department for Science, Innovation and Technology, UK Government, U.K.

Someya, Takao, Professor, The University of Tokyo, Japan

Turekian, Vaughan C., Executive Director, Policy and Global Affairs Division (PGA), National Academy of Sciences (NAS); former Science and Technology Adviser to the Secretary of State, Department of State, U.S.A.

VijayRaghavan, K., Former Principal Scientific Adviser to the Government of India, National Centre for Biological Sciences; DAE Homi Bhabha Chair, National Centre for Biological Sciences, TIFR, India

Parikh, Sudip S.

Opening Remarks

At the start of the session, the chair introduced the three main pillars of the framework for science diplomacy: science in diplomacy, diplomacy for science, and science for diplomacy. The chair commented on the accelerating rate of change happening globally, how international scientific collaboration may be impacted, and how scientific knowledge and expertise can help to inform diplomatic objectives.

First, the speakers discussed the development of innovation and technology centers in Africa, the role that science diplomacy and partnerships will play in future initiatives over

the next 10 years, and the importance of knowledge-sharing between nations. They raised the concern of being able to quickly respond to humanity's needs and the current state of working with regulatory authorities to create a supportive environment for tackling those issues.

The speakers highlighted the value of mutual understanding, that people were the core of science and diplomacy, and how government can help facilitate initiatives and cooperation between parties. The speakers emphasized that science is fundamentally an international endeavor as no entity is an expert in all areas, that resource-sharing even with your greatest competitors has worthwhile benefits through diplomacy, and that relationships underpin all diplomacy.

The speakers emphasized the significance of cross-border collaboration to drive innovation through initiatives such as open and international talent-exchange to encourage the free flow of ideas between countries, as well as the need to develop a global startup ecosystem to help address global challenges. The speakers also stated the importance of research security, including for the promotion of international joint research.

The speakers also raised the issue that the era of globalization is facing increasingly existential threats, particularly in the science and technology space, and that science and diplomacy should not have any disconnect with national priorities as that would lead to limiting success. The speakers then noted how geopolitics can influence changes within organizations over time, and the importance of finding systems, approaches, and models to bring multi-stakeholder communities together.

The speakers highlighted the concerns within the current political landscape, areas where non-scientific entities are entering into discussions where science should take precedence, and the communication challenges that could potentially arise between diplomats and scientists. The speakers also noted the importance of raising complex issues in an easy-to-digest manner, particularly in the energy, agriculture, and healthcare spaces, and of enabling countries to utilize all the tools available to address complex challenges.

Discussion

In the group discussion, the participants identified issues that inhibit and prevent collaboration, and recommended building and maintaining capacity to help promote collaboration, such as through helping train younger generations.

The group also discussed the importance of research security, the influence of politics on science diplomacy, and the disparity between today's political rhetoric and actual scientific data. They also noted events of hostility towards science which could translate into political action, but also the need for political regulation in science such as with the development of AI.

The participants then questioned who should help lead science diplomacy, such as public servants, scientists, university administrators, or those in industry, as there are many actors and stakeholders with varying goals. They also raised the issue of trying to have as much openness as possible while still creating larger scale diplomacy when engaging in international collaboration.

The group also commented on bridging the gap between diplomats, who primarily serve their country's national interests, and scientists, who typically prioritize cooperation for the common good, particularly when science diplomacy is becoming increasingly critical as we face global challenges that cannot be addressed by one nation alone. The integration of diplomats and scientists is essential in fostering communication between governments and the global scientific community. This is why professional science advisors play a pivotal role in translating technical knowledge into policy that diplomats can understand and act upon.

The participants also noted the challenges in ensuring a level playing field globally when addressing societal issues, in developing capacity in areas that are most in need, and in technology transfer and making knowledge available to those who need it most. They agreed that building elements of true reciprocity in collaboration and promoting the mobility of scientists internationally would be particularly constructive.

The group also highlighted the importance of education and creating a pipeline of those educated in science diplomacy, financing or the lack thereof, the risk of not including industry in conversations, as well as recognition of the balance between optimism and healthy skepticism and being able to acknowledge political realities.

The participants concluded by recommending that instead of becoming stewards of the organizations that we have inherited, we should become leaders of those organizations and build upon the foundation laid by the generations before us.

Cooperation in S&T

Collaboration among Academia, Industry and Government

[Chair]

Quirion, Rémi, Chief Scientist of Quebec, Office of the Chief Scientist of Québec, Canada; President, International Network for Governmental Science Advice (INGSA), New Zealand

[Speakers]

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

Colombani, Pascal, Chairman Emeritus, Valeo; Former Chairman and CEO, Atomic Energy Commission (France), France

Hu, Jianying, IBM Fellow; Director, HCLS Research; Global Science Leader, AI for Healthcare, IBM, U.S.A.

Uehara, Natsuko, Executive Officer, National Institute of Advanced Industrial Science and Technology (AIST), Japan

Dasher, Richard B., Director, U.S.-Asia Technology Management Center, Stanford University; Founding Partner, Global Hands-On Venture Capital (GHOVC), U.S.A.

Tveit, Mari Sundli, Chief Executive Officer, Research Council of Norway (RCN), Norway; President, Science Europe, Belgium

Loesekrug-Pietri, André, Chairman & Scientific Director, Joint European Disruptive Initiative (JEDI), the European ARPA, France

Opening Remarks

Quirion, Rémi

To begin the session, the chair commented on the importance of collaboration especially in a rapidly changing world, noting the speed at which society was able to discover a vaccine for COVID-19. However, access to the vaccine remained a challenge, particularly in the Global South. The chair also focused on the issue of trust. Given the exchanges raised by citizens and various communities in society who can oftentimes be left out, the need to increase education particularly in scientific and digital literacy was stressed.

First, the speakers talked about the current issue of political attacks against science, the benefit of running campaigns to gather Nobel laureates to help support governments around the world, and the advantage of publishing in open journals as often as possible. The speakers emphasized that being able to gather groups of people with good ideas can prove highly beneficial in reaching goals. The speakers also noted that genetically modified organisms were important to solve hunger problems as well as to help solve climate change.

The next topic of discussion was on how governments should provide further support for long-term strategies, define which areas should be prioritized in view of the needs of the population, provide easier access to capital for new ventures, as well as provide tools that alleviate technology concerns. Academia should therefore ensure excellence in fundamental research and the development of a new generation of talent. Academia and industry should develop appropriate structures to ensure the efficient transfer of research results to industry and services. Markers of success for industry included the introduction of new services in a large productive market thus imposing norms on a global scale.

The speakers then spoke about the differing perspectives on what is prioritized in collaboration between industry, academia and government in order to maximize the advancement of science and technology while reducing risk. Top priorities include: driving open innovation to achieve scale and access, ensuring trustworthiness by establishing consensus on

guardrails, policies and metrics, and achieving equity through cross-sectoral collaboration. The speakers also noted the government's role to function as an equalizer and enabler through thoughtful distribution of resources.

The speakers also commented on both global and local challenges in collaboration, some of the hurdles in building mutually beneficial partnerships, and issues that arise when dealing with non-disclosure and confidentiality agreements and their effects on productivity. They also touched upon the intensifying global competition for talent, particularly in Japan, and noted steps taken to increase leadership capabilities among that talent.

The speakers noted that most collaborations consider the supply side but emphasized that the demand side must be accounted for. The government plays a particular role in recognizing standards and measurements and is itself the most efficient way to harmonize the actions of sectors worldwide. The system works when all sectors recognize the interdependence of their roles and the limitations of their individual work.

The significance of driving relevant and efficient research to address specific challenges was also discussed. Achieving collaboration between sectors is vital, and a key element of fostering collaboration will always be trust, which must be continuously cultivated and curated. Trust, human interaction, and supportive funding structures are key enablers of this collaboration, and by working together, it is possible to overcome challenges and continue to drive innovation and value creation.

The speakers highlighted the incredible acceleration of technology, with the availability of high performance computing, huge databases and the exponential accumulation of data, the impact of artificial intelligence, and new means of developing new products faster through simulation, but also the growing sentiment of uncertainty among citizens regarding the fast pace of technology, as well as the need to keep political leaders up to date on scientific innovations in order to help them make informed decisions.

Discussion

The participants then held a group discussion, touching upon the current lack of political leadership, the issue of prioritization of research topics, and a lack of awareness and increasing amounts of conflicting information among the general public. They also noted the importance of bridging the gap between academia, industry, and government, and of accelerating that process.

Following this, the participants spoke about challenges in educating the general public, the varying views among different institutions on the same topic, and the difficulty in quantifying some scientific information. Solutions discussed included the training of scientists and engineers in education, teaching scientific communication as part of university curriculums, and the development of a platform for communication between parties to have a common user experience. They added that building trust was vital as many are afraid of bias and conflicts of interest, and that developing incentives for collaboration could be beneficial. Noting the tendency among public influencers to use "expert" analyses to spread misinformation, participants emphasized the need for better public education on distinguishing credible information from manipulated data. Industry funding for academia could also prepare the next generation to fill gaps in the market.

The group then highlighted some characteristics of the Global North and the Global South, noting that research and development probably resides more within academia than within industry in the global south. Understanding the ecosystem of the region that you are working in is important. The participants also emphasized the significance of accepting funding from the resources being utilized.

The participants emphasized engaging in open communication, pointing out that scientists should step out of their silos to influence policy. They added that scientific literacy, knowledge brokerage, and education were important pieces of the puzzle to help advance communication and ensure the general public is well informed. Practical steps to foster collaboration included the enhancement of incentives, providing greater access to capital, and multidisciplinary training to create global citizens who can understand the complex challenges of our time. They also emphasized the importance of creating value that would be recognized by the people.

The group then shared ideas on disruptive innovation, ways to stimulate innovation, and the importance of clear, purpose-driven, top-down, human-centric, and sustainable and resilient solutions. They also commented on challenges with regulation, urged the sharing of experiences, and advocated for the support of all countries including developing nations. In conclusion, the participants were focused on education, the dissemination of information, and communication.

Cooperation in S&T

Nurturing Innovation-based Startups

[Chair]

Copan, Walter G., Vice President, Research and Technology Transfer, Colorado School of Mines; former Director, National Institute of Standards and Technology (NIST), U.S.A.

[Speakers]

Boonfueng, Krithpaka, Executive Director, National Innovation Agency (NIA), Thailand

Fujimori, Yoshiaki, Chairperson of the Board of Directors, Oracle Corporation Japan; Senior Executive Advisor, CVC Japan, Japan

di Luccio, Eric, CTO, Head of R&D, Executive Officer, HIROTSU BIO SCIENCE INC., Japan

Navani, Rajan, Chairman & Managing Director, Jetline Group of Companies - Jetsynthesys Pvt Ltd; India

Rahim, Rushdi Abdul, President & Chief Executive Officer, Malaysian Industry-Government Group for High Technology (MIGHT), Malaysia

Zurbuchen, Thomas, Director, ETH Zurich Space, ETH Zurich, Switzerland

Opening Remarks

To start the session, the chair spoke about how startup enterprises are developed to commercialize technologies and, in the process, can disrupt markets through creative destruction. Startups are the foundation of industrial mutation, and important to drive evolution and those changes that will ultimately replace the old while creating the new. Startups are essential to the resilience and competitiveness of economies globally. Building and sustaining ecosystems of innovation success can help develop a culture that attracts entrepreneurial talent and investment, embraces intelligent risk-taking, and enhances the rate of success of startups.

Copan, Walter G.

The next speakers made remarks on the startup culture in Thailand, the support provided by the government, the focus on technology, and the current state of development of a new generation of entrepreneurs. The speakers also noted the importance of having a global mindset, of global collaboration, and of having a platform to help nurture innovation-based startups.

The speakers discussed the profound impact of cancer screening technologies, the development of new early-detection non-invasive cancer screening tests, its relation to AI and machine learning, the economic scale-ability of these technologies, as well as the rate of acceleration of the development of these technologies and their impact on communities globally.

The speakers then discussed the development of pyrite-based solar cells in the renewable energy sector and their potential use as an alternative, particularly due to their cost effectiveness, material abundance, stability in room temperature and other favorable properties, benefits to the environment, and potential commercial applications. They also spoke about the work culture in Japan as it relates to startups and the importance of international collaboration among Japanese corporations.

The speakers also commented on the mindset of successful innovators, the impact of technology on innovation, the gap between aspiration and resources, as well as the importance of finding the right people. They added that the startup phase is only the starting point and

that another transition and a different mindset are required in order to scale a startup into a successful platform.

The speakers then stated the importance of context-based methods in helping develop a healthy startup ecosystem, provided examples of the ambitious advancements taking place in Malaysia to develop those ecosystems, and noted the benefits of collaboration between multiple ministries and agencies. They also touched upon the development of roadmaps, the need for industry participation, and the challenges around regulation in Malaysia.

The speakers lastly highlighted the significance of having a benevolent institutional anchor, such as a university, government entity, or company, in a collaborative environment, the density of the talent base within the startup development ecosystem, the ability to build teams, being able to develop a common language and mindset, the evolution of an idea as opposed to the original idea itself, as well as how funding can influence incentives. Without an entrepreneurial funding mechanism, an innovation ecosystem is as efficient as clapping with one hand.

Discussion

The participants then held group discussions where they emphasized the importance of having an anchor to help develop a collaborative ecosystem, of attracting and having access to high level talent and the risk-taking capacity of that talent base, as well as the tolerance of failure within these ecosystems.

The participants then shared views on the role of government to help derisk entrepreneurial ecosystems, the development of policies to attract funding, the development of strong legal frameworks for the utilization of convertible loans and to protect startups from bankruptcy, the need for protection from theft of intellectual properties, and the value of expanding networks and communications to build trust among stakeholders. They also commented on challenges during the scale-up phase of startups, noting that risk was context based and that, as a result, nurturing the entrepreneurial mindset would be significant.

The participants also spoke about the benefits and challenges of incubators to support promising startups, the breadth and influence of the cultural backgrounds of entrepreneurs, as well as the issue of aging populations particularly in Thailand and Japan.

The participants then discussed the impact of investors, the necessity of having an investor who was local, the ratio of supply to demand, the importance of having a sizable financing round to attract international investors, and the possible benefit of having matching funds for both local and foreign investors to encourage more foreign investment. They also commented that the valuation of startups was abstract and spoke about the challenges of having an entity being overvalued or undervalued, especially in ecosystems where the funders are not very experienced with startups.

The participants also examined best practices, highlighting integrating education programs as early as possible, the need for further collaboration among universities and corporations, and the benefit of creating a network to develop a more collaborative startup environment, especially as it relates to training budding entrepreneurs on how to handle failure. They added that anything that promotes the ease of doing business was beneficial. The participants concluded by noting the importance of creating a regulatory framework that is both agile and friendly.

S&T Education

Fostering New Generations of Scientists with Inclusion and Diversity

[Chair]

Carrozza, Maria Chiara, President, National Research Council (CNR), Italy

[Speakers]

Yeh, Nai-Chang, Thomas W. Hogen Professor of Physics, Physics, California Institute of Technology (CALTECH), U.S.A.

Moloney, Michael H., Chief Executive Officer, AIP – American Institute of Physics, U.S.A.

Kirloskar, Geetanjali Vikram, Chairperson & Managing Director, Kirloskar Systems Private Limited (JV partner of Toyota Motor Corporation), India

Opening Remarks

The chair opened the session by emphasizing the crucial role of science and technology (S&T) in addressing global challenges. Its quality and impact, however, largely depend on selection of the best talent, regardless of age, gender, socioeconomic background, or cultural factors to ensure a richness of backgrounds and plurality of perspectives. A robust science ecosystem relies on diverse knowledge from a multitude of fields; therefore, reflecting on diversity in the sciences should be a multidisciplinary undertaking. The chair highlighted the importance of nurturing a new generation of scientists by promoting greater diversity and ensuring fair, collaborative, and inclusive environments.

Carrozza, Maria Chiara

The speakers pointed out the abundant evidence throughout history for diversity's positive impact, since most pinnacles of civilization were achieved when society embraced diverse ideas, people, and cultures. Fields such as condensed matter physics are highly interdisciplinary as students from a wide range of technical and cultural backgrounds who are capable of thinking beyond their own comfort zones are involved. To achieve significant improvements in diversity at institutions

for science education and research, recognizing excellence in an objective manner, building support networks for underrepresented groups, and championing role models to foster diversity and science are crucial.

The importance of a robust talent pipeline was discussed by the speakers in addressing challenges such as global pandemics, the climate crisis, and ethical applications of AI. Conducting detailed statistical studies on diversity and inclusion using social science techniques is a way to identify issues and implement recommendations for improved, more inclusive environments to empower future generations of scientists. To foster a robust talent pipeline we must promote a sense of belonging and develop best practices. While diversity in STEM teams drives global economic growth and thereby creates a more competitive workforce, it also contributes to a more equitable science community which is essential for solving complex global challenges.

The speakers discussed India as one example of an inherently highly diverse country, focusing on the country's efforts to address gender diversity in science and technology during the past decades. To achieve this, government-mandated affirmative action programs and schemes to ensure greater participation of women in STEM fields were implemented. While the percentage of women scientists has risen, the number of women opting out of STEM mid-career due to socio-cultural pressure remains significant. Role models can have

a positive impact and the female scientists of the Indian Space Research Organization (ISRO) contributing to India's 2023 lunar mission, who have received high media coverage, were given as one specific example.

Discussion

The participants addressed the question of whether diversity remains a problem in science and technology today. While many actions are being taken to address diversity and inclusion issues, challenges persist across different countries and contexts. Regarding gender quality, while women are underrepresented in STEM in Europe, they comprise the majority of university students in Qatar. Furthermore, institutions taking different approaches to address unconscious biases were discussed. For example, the National Research Council of Italy created a video on the topic that selection committee members must watch before reviewing candidates' CVs.

The participants' discussion then turned to enabling research opportunities for people facing workplace access difficulties, such as people with disabilities or those on maternity leave. Using "smart working" and other new tools to accommodate diverse needs was proposed. Regarding people with disabilities in science and technology, the Shaffalah Center in Qatar was brought up as one successful example. The issue of brain drain was also raised, with some countries losing young STEM researchers to better opportunities abroad. Participants suggested that governments and institutions should make increased investments in researchers and provide career incentives for them to return to the respective countries after stays abroad.

Following this, the participants emphasized the importance of inspiring an affinity for science from a young age, particularly among girls. They discussed the need for greater socio-cultural evolution to break stereotypical roles and allow women to progress in scientific careers. The concept of role models was further explored, with the suggestion that success criteria for these models should be carefully defined. The group also addressed the evaluation criteria for women's careers in organizations, noting that the idea of a successful career should be shared by both male and female researchers.

The participants stressed the importance of ensuring a variety of paths for career advancement. The way women and minorities are influenced at a young age by their family, schoolteachers, and peers regarding science is one aspect that deserves attention. Also, curriculum structure was identified as a potential factor impacting participation of women and under-represented minorities in STEM. The use of social media to spark interest in science among younger generations was suggested as a possible approach to ensure greater diversity going forward.

Concerning the use of AI, the participants pointed out that the science community needs to be aware of the inherent bias of AI regarding diversity and inclusion. The participants commended concrete initiatives to facilitate diversity, such as the childcare service offered at this year's STS *forum* to accommodate the different needs of participants.

S&T Education
AI in Education

[Chair]
Aoun, Joseph E., President, Northeastern University, U.S.A.

[Speakers]
Ataka, Kazuto, Professor, Faculty of Environment and Information Studies, Keio University; Senior Strategist, LY Corporation, Japan
Flandrin, Patrick, Director of Research (DRCE2), French Academy of Sciences; Director of Research, Physics Laboratory, The French National Centre for Scientific Research (CNRS), France
Hacid, Hakim, Chief Researcher, Artificial Intelligence and Digital Science Research Center, Technology Innovation Institute, U.A.E.
Marwala, Tshilidzi, Rector, United Nations University; Under-Secretary-General, United Nations
Wirahadikusumah, Reini, Rector, Institut Teknologi Bandung (ITB); Professor, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung (ITB), Indonesia
Zacharia, Thomas, Senior Vice President, Strategic Technology Partnerships and Public Policy, AMD, U.S.A.

Opening Remarks

The chair started the session by highlighting two perspectives on AI's impact on higher education: integration and disruption. As each institution makes AI integration efforts, AI technology will become a commodity not unique to one institution. The need to rethink curricula was emphasized and the concept of "humanics," which comprises technology, data, and human literacies, was introduced. While boundaries between capabilities of machines and humans are constantly changing and AI is becoming ubiquitous, experiential learning and lifelong education are crucial in light of aging populations and rapid technological advancement. The struggles of universities to keep pace with industry in generative AI research due to funding limitations were addressed and their future role was questioned.

Aoun, Joseph E.

The speakers stated that higher education is at a pivotal moment in the face of the rise of AI, highlighting its current use and ability to outperform humans in many cognitive tasks. Seven key areas were proposed to adapt education systems: curriculum restructuring, innovative teaching methods, research reformation, industry collaboration, globalization, lifelong learning, and faculty role redefinition. Emphasis was placed on developing critical thinking, creativity, and ethical reasoning while leveraging AI, stressing the importance of preserving human values and preparing students for future societal roles. These challenges should be addressed from the basic education stage.

The speakers emphasized AI's growing importance across all fields of human activities, describing ChatGPT's release as a game changer. Two approaches to AI in education were presented: preparing students to passively use AI, or to actively work with it. While AI's output for translation, language learning and teaching, and text production is impressive, questions surrounding explainability and biases remain. Humans must stay in the loop, viewing AI as an assisting tool rather than a substitute for human intelligence.

The speakers discussed educators' concerns surrounding differentiation between student and AI-produced work. Although large language models (LLMs) are promising, their reasoning capabilities remain limited. As existing assessment methods are time consuming, there is potential for AI to contribute to a reduction of instructor workload, thereby enabling a focus on education quality. Furthermore, AI-based assessment of educational institutions could contribute to increased objectivity by removing the human

factor. While AI can generate individual teaching sessions, creation of a comprehensive course curriculum is beyond its capabilities.

The speakers outlined four key issues concerning the technological aspect of AI in education: data, algorithms, computing, and applications. Related challenges range from data literacy to energy consumption of CPUs. The importance of agreeing on values such as transparency, explainability, and security was highlighted. Additionally, the need for cautious technology adoption, training students in verification, and university structures that involve multidisciplinary expertise going beyond technological knowledge were discussed. Regarding policy and regulations, a balance must be found to foster opportunity seeking while factoring in risks.

Indonesia was discussed as one example of a country advancing initiatives for AI integration in higher education. For instance, Institut Teknologi Bandung (ITB) established multiple campuses to facilitate access in different regions, and AI can further enhance accessibility. The institution's concrete efforts are the creation of a task force involving students, faculty, and staff, participation in national AI strategies, and a reformed curriculum focusing on AI literacy, creative and critical thinking, interdisciplinary education, and lifelong learning.

Lastly, the speakers looked at AI from an industry perspective, pointing out that the fast pace of development exceeds human comprehension. AI demand across industries such as manufacturing, logistics, services, and healthcare will lead to enormous hardware and power demand. As demand projections become quickly outdated, a fundamental rethinking toward solution-focused computing is necessary. With transformation rapidly advancing and affecting all aspects of life, educational institutions must reassess their fundamental structure as well.

Discussion

The participants questioned the purpose of higher education, as many faculty members' main interests are within research rather than teaching. AI utilization can contribute to decreasing faculty workload, while providing students with personalized education. However, while AI-enhanced evaluation methods are promising, final assessment by humans remain necessary. AI may also provide solutions for the North-South divide by mitigating the lack of educators for basic education in mathematics or English in less privileged countries.

The participants reflected on the importance of educational institutions having an AI strategy that involves stakeholders from all different levels—such as students, faculty, and university leaders—and encompasses curriculum development and faculty training. Benchmarking against AI initiatives of other institutions was suggested to foster development of effective strategies.

Additionally, AI's benefits for education and analysis of its human-centric aspects were highlighted by the participants, as they have potential to become an enabler for productivity by inspiring new ideas in students. The challenges related to regulations, as well as possibilities and resources for AI implementation vary by country.

Subsequently, the participants questioned AI's capability to create bridges and greater inclusion. In the process of reshaping education, the nature of teaching itself may change, and the concept of "super teachers" emerging across various disciplines through AI technology to shape future education models was explored. As a consequence of AI's impact on scientific research, the possibility of a renewed focus on philosophy and social science was discussed.

Increased interdisciplinary collaboration and teamwork made possible by AI freeing up time for more human interaction and project-based learning was also discussed. AI can foster curiosity, improve question-asking skills, and enhance motivation among students. As AI changes the nature of education, participants recommended concentrating on developing future-proof skills such as creativity, negotiation, problem-solving, and teamwork.

Lastly, the participants reflected on the limitations of AI in education. While it can support various aspects of the education process, critical analysis of the validity of information is beyond its capability and the experience of engaging with diverse individuals cannot be replicated. The participants therefore concluded that the integration of AI in education should ultimately aim to enhance human capabilities and interactions rather than replace them, emphasizing that humanity should remain at the core of educational approaches.

S&T Education
Signaling the Trustworthiness of Science

[Chair]

Tschinkel, Yuri, Executive Vice President, Mathematics and Physical Sciences, The Simons Foundation; Professor of Mathematics, Courant Institute of Mathematical Sciences, New York University, U.S.A.

[Speakers]

Fujigaki, Yuko, Executive Vice President, Professor, The University of Tokyo, Japan

Hassink, Laura, Managing Director, STM Journals, Elsevier, Netherlands

Hoch, Michael, Rector, University of Bonn; Chair, German U15 e.V., Germany

Markides, Karin, President and CEO, Okinawa Institute of Science and Technology (OIST), Japan

Nelwamondo, Fulufhelo, Chief Executive Officer, National Research Foundation (NRF); Chief Executive Officer, National Research Foundation, South Africa

Raghavan, Padma, Vice Provost for Research and Innovation, Chief Research Officer, Senior Advisor to the Chancellor and Distinguished Professor of Computer Science, Vanderbilt University, U.S.A.

Schmidt, Brian P., Distinguished Professor, Research School of Astronomy and Astrophysics, The Australian National University (ANU), Australia [Nobel Laureate 2011 (Physics)]

Tschinkel, Yuri

Opening Remarks

At the start of the session, the chair raised questions about definitions of evidence and proof. As standards vary across scientific disciplines, there is a need for well-functioning verification mechanisms such as peer review, data sharing, and transparent processes. The challenges of overstating results in competition for funding resources and the importance of effective science communication to maintain public trust were also addressed. As one example, the concept of proof in mathematics was discussed,

noting how new technologies from computer science are being used to verify complex mathematical proofs.

First, the speakers addressed trustworthiness regarding disseminating scientific knowledge through journal publishing. Recently, this area is facing many challenges posed by generative AI, as the volume of fraudulent content is increasing. Investments in human oversight and AI technology to detect any cases that could compromise trust in science are being increased to address these issues.

Next, the speakers' discussed constant change being an inherent feature of scientific knowledge. However, a large part of the general public has an image of scientific facts being fixed, and contradicting research results can lead to distrust. This gap between reality and perception can cause a loss of trust in science. Effective efforts by science communicators and examination of different approaches for disclosing information are key elements for achieving trustworthiness.

The speakers stated that excellent science requires societal trust, and that scientific freedom must be ensured by governments. During the COVID-19 pandemic, in some countries the credibility of science itself came under scrutiny as a result of conflicting statements by scientists in the media. The importance of accurately conveying the nature and limitations of science to the public and educating young generations on research integrity from the undergraduate level onward was stressed.

Then, the speakers concentrated on the rigorous scientific peer review processes carried out for the verification of research findings. This high standard and self-discipline safeguard the verity which also means that even the smallest evidence of falsified data publication would be detrimental to careers in science. The complexity of collaborating and communicating with the public was addressed, and the speakers highlighted that trust-building requires verified knowledge of data from all included disciplines in multidisciplinary findings. This ability must be prioritized in order to lead society toward a sustainable future.

The challenges of coexistence with AI were also explored. AI is testing the current understanding of science as being knowledge-based, reputable, and verifiable. In light of technological advancement, the need to redefine science was discussed, and reassessment of the roles of peer review, criticism, and public engagement was suggested.

The speakers also examined the intersections of government, the public, and science, pointing out differences across countries and regions. In particular, the current historically low trust in government and scientists in the U.S. poses challenges for universities, calling for a greater need for institutional neutrality and the demonstration that evidence-based research is the foundation of science.

Lastly, the speakers pointed out the effects of the internet enabling easy access to and dissemination of information, leading to less influence of mainstream media and experts while politicians were turning increasingly populist. Consistently ensuring transparency in science should be a guiding principle. Ways to achieve this are guaranteeing that research is open and reproducible, reacting to misconduct based on internationally agreed regulations, and involving the community through co-creation of science.

Discussion

The participants discussed the changing levels of trust in science across different countries. While trust levels have remained stable in Sweden over the past decade, the U.S. has seen a notable decline. Regarding solutions to improve the public's understanding of science, suggestions were made to focus on teaching how to identify facts rather than simply conveying knowledge.

The participants also highlighted the need to clearly distinguish between scientific facts and policy decisions based on them, and the positive impact of scientists as approachable role models to inspire children to become scientists themselves. The role of social sciences and humanities in facilitating conversations around trust in science with the general public was acknowledged as an important area for further exploration.

Next, the participants addressed the importance of institutional neutrality for universities and research institutions, particularly during times of crisis, and emphasized the need for thorough communication strategies to maintain public trust. Equally, trust among scientists is of great significance, and further improvement of journal article review processes can contribute to enhance it.

The participants' discussion shifted to effective methods for communicating science to the general public. Remarks were made on the multidimensional nature of this process, as the inherent self-correction prevalent in science may lead to erosion of trust. Transparently acknowledging uncertainties and implementing codes of conduct and awareness guidelines can contribute to a better understanding by the general public.

Then, the participants touched on the balance between ensuring academic freedom and maintaining public trust, concluding that science does not exist in isolation, but must address the real needs of society. An initiative for virtual classroom programs in Finland that connects researchers with school children was cited as a specific example of effectively fostering curiosity and a deeper understanding of science among the young generation.

Taking responsibility for the trend in distrust was recommended by the participants and using language that can be easily understood by the public was pointed out as effective. As the truth is constantly evolving, communication of scientists with young people to educate them on the nature of science is vital.

Digital Technologies
Countering Disinformation in Digital Age

[Chair]

Ito, Joichi, President, Chiba Institute of Technology; Co-founder and board member, Digital Garage, Japan

[Speakers]

Larson, Heidi, Professor of Anthropology, Risk and Decision Science, Infectious Disease Epidemiology and Dynamics, London School of Hygiene and Tropical Medicine, U.K.; Clinical Professor, Institute for Health Metrics & Evaluation, University of Washington-Seattle Campus, U.S.A.

Mochizuki, Yasunori, NEC Fellow, NEC Corporation, Japan

Dowling, Michael, Chairman of the Board, MÜNCHNER KREIS; Prof. Dr., Faculty of Business and Economics, University of Regensburg, Germany

Toope, Stephen J., President and CEO, Canadian Institute for Advanced Research (CIFAR), Canada

Opening Remarks

The chair opened the session by noting the increasing importance of disinformation with the rise of AI and deep fakes, highlighting the impact of disinformation in global events such as the 2016 US elections, Brexit in the UK, and the COVID-19 pandemic. The chair emphasized the need to discuss the topic from both a practical and a research perspective, noting recent studies on the effectiveness of community notes on platforms like Twitter.

Ito, Joichi

Following this, the speakers emphasized the urgency of adopting a systems approach to address disinformation, moving beyond simple fact-checking, and stressed the need for a portfolio of methods to combat various forms of harmful content, including addressing fear-mongering and ambiguous messaging. The speakers also highlighted the importance of considering offline information exchange and the challenge of monitoring private spaces while being sensitive to privacy rights.

Next, the speakers discussed how the awareness of disinformation is also growing in Japan, noting that fake rescue requests were made after the Noto Peninsula earthquake in January, as well as an increase in financial fraud attempts. The speakers noted that AI-based solutions to combat disinformation are now under development in Japan. The speakers emphasized the need for a comprehensive approach, including information sharing, legal frameworks, and educational initiatives to enhance public literacy, and also highlighted the G7 leaders' agreement on the Hiroshima AI process and Japan's efforts to educate young children about disinformation through YouTube videos.

The speakers then discussed the problem of deepfakes, noting the challenge they pose to human perception of truth. The legal challenges in addressing these issues were pointed out, noting that laws had not kept up and were often unable to address the problem. The speakers expressed optimism about technological solutions for identifying deepfakes but also stressed the importance of public education in critical media consumption and the need for creative regulatory approaches.

The next topic of discussion was the erosion of trust in research and knowledge due to misinformation and disinformation, noting the relative nature of truth in group dynamics and the need for science to engage more with communities. The speakers highlighted the

need for collaboration across sectors to address disinformation and the role of public trust in institutions.

Discussion

Following the opening remarks, the participants engaged in a discussion. They began by touching on how fundamental the trust issue is, and exploring the issue of accountability in online platforms, with participants considering the idea of requiring users to verify their identities. While this approach could increase accountability, concerns were raised about its potential to endanger individuals in repressive societies who rely on anonymity. The conversation then shifted to geopolitical implications of AI development, with concerns expressed about the possibility of only a select group of countries (the "Five Eyes plus Japan and Korea") having access to advanced AI models, potentially exacerbating global inequalities and becoming part of statecraft.

The participants drew parallels between cybersecurity and countering disinformation. They suggested that strategies from cybersecurity, such as regular training courses, simulated attacks, and real-time information exchange through Security Operational Centers, could be applied to combating disinformation. However, they acknowledged that the rapid spread of disinformation poses unique challenges. The need for better coordination and information sharing between platforms and affected parties during disinformation attacks was highlighted, with participants noting current limitations in this area, such as platforms not being permitted to inform recipients about disinformation attacks.

The discussion delved into philosophical questions about the nature of truth and information in the digital age. Participants grappled with the difficulty of determining authentic information in an era of generative AI and its implications for human autonomy. Some argued for a pragmatic approach to truth, viewing it as the best explanation based on available data and reasoning, while acknowledging its provisional nature. Cultural differences in approaching AI development were explored, contrasting Western views of control with Eastern perspectives that emphasize autonomy and harmony within systems, using the Japanese concept of "omotenashi" as an example.

Addressing trust issues emerged as a crucial theme, particularly in the context of aging societies and local communities. Participants shared examples of how misinformation has disrupted family and community relationships, such as the case of a medical professor unable to convince his mother to get vaccinated against COVID-19. The discussion highlighted

the need for scientists and experts to engage more actively with public concerns, moving beyond simply asserting expertise to understanding and addressing underlying issues. The importance of acknowledging uncertainty in scientific processes was emphasized as a way to build trust.

The conversation touched on the challenges posed by deep fakes and manipulated media. While some participants suggested that the widespread ability to create such content might lead to increased skepticism, others pointed out the potential for harm, especially to vulnerable individuals. The discussion concluded with reflections on the rapid pace of technological change and its impact on regulation. Participants acknowledged that while regulation often lags behind technology, good regulation is still necessary and can make positive improvements, such as in the case of environmental and tobacco regulations. However, they stressed the need to improve the speed of developing regulations to keep up with the speed of change. They also discussed the potential for new technologies, including AI and multimodal systems, to both exacerbate and potentially help solve disinformation challenges, emphasizing the need for adaptive and forward-thinking approaches to policymaking.

Digital Technologies
Cybersecurity

[Chair]

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

[Speakers]

Baloo, Jaya, Chief Security Officer, Rapid7, U.S.A.

Métral, Pascal, Vice President Legal Affairs and Head of Intelligence, Investigations and Litigation, NAGRA Kudelski Group, Switzerland

Perrig, Adrian, Full Professor, Department of Computer Science, ETH Zurich, Switzerland

Günther, Oliver, President, University of Potsdam, Germany

Mencer, Oskar, CEO, Maxeler Technologies, a Groq Company; U.K.

Opening Remarks

The chair started by emphasizing the critical nature of cybersecurity, citing recent breaches seen in the news like the Salt Typhoon group attack, pointing out that cybersecurity is not just a topic for discussion but one that requires action.

Following this, the speakers cautioned that we may be becoming desensitized to cybersecurity topics due to the high number of incidents. The speakers discussed examples of significant cyberattacks, including Stuxnet in 2010, which was designed to spread until it found the software controlling a specific centrifuge in Iran, causing it to explode, and also the BlackEnergy malware attack on the Ukrainian power grid in 2015, and the ransomware attack on Colonial Pipeline. The speakers emphasized that energy sector infrastructure is particularly critical and vulnerable, and pointed out that over 80% of the problems could be solved by implementing multifactor authentication (MFA) and patching known vulnerabilities in systems.

Spiropulu, Maria

The next topic of discussion was the future of cybersecurity hygiene. The speakers emphasized the importance of the human factor in cybersecurity and discussed the challenges of predicting technological advancements. They suggested that certain fundamental aspects of cybersecurity, such as the need for securing data and privacy, would likely remain constant in the coming decades. The speakers also raised questions about the future of cryptocurrencies, their impact on cybercrime, and how quantum computing, regulation and other developments would impact their use.

The speakers then discussed the importance of the availability aspect within cybersecurity, considering what society would look like without the internet. The speakers considered the fundamental question of how secure a global network can be and highlighted a newly developed secure internet architecture called SCION, which offers multiple path options for communication, based on various criteria, allowing for enhanced security, performance, and quality. The speakers noted that this SCION architecture has been in active deployment since 2017 and operates alongside the current internet, offering users a choice between traditional protocols and SCION's secure paths.

Next, the speakers discussed the challenges of administering devices in a security-aware manner to minimize the risks of attack, giving the example of a large organization like a university, where there is an inherent tension between maintaining an open academic

environment and implementing necessary security measures. The speakers noted that measures against cyber risks fell into three categories: personnel, organizational, and technical. The speakers emphasized the importance of training staff and students, maintaining a clear inventory of IT resources, and implementing technical measures to provide reasonable security while balancing the need to preserve the open nature of academic institutions.

The speakers then focused on the impact of AI, particularly large language models (LLMs), on cybersecurity. They discussed how the rapid advancement of AI has shifted the landscape of cyber threats and opportunities, and highlighted the potential for manipulating language probabilities in LLMs, which could be used to influence opinions or spread misinformation. The speakers emphasized the need to consider the consequences of AI capabilities and to determine who should have access to various technologies.

The speakers also discussed the development of post-quantum cryptography standards, highlighting the importance of public-private partnerships in addressing cybersecurity challenges. They noted that three recently issued NIST standards for post-quantum cryptography aim to protect critical infrastructure and federal protocols against future quantum computing threats. The speakers emphasized the sophistication of these new encryption systems and their importance in preparing for the potential power of quantum computing to break current encryption methods.

Discussion

Following the opening remarks, the participants engaged in a group discussion covering various aspects of cybersecurity and artificial intelligence. The participants identified ransomware, supply chain integrity, and the threat of China using cyberattacks as key concerns. They also discussed the challenges of affordability of cybersecurity with limited resources, and the potential need for a "benevolent dictator" to be able to address certain cybersecurity issues effectively.

The discussion also focused on the impact of generative AI on current cyber threats. The participants highlighted the increased volume of attacks and variants generated by AI, making it even more difficult for individuals to maintain sufficient levels of cyber hygiene. The concept of "brain attacks" and AI-powered influencers affecting public opinion was also discussed. The participants explored the idea of private active cyber defense, debating the principles of equality of arms and whether digital retaliation should be acceptable. They considered scenarios such as recovering decryption keys from attackers and discussed the limitations of existing legal frameworks.

The discussion then turned to attitudes towards large language models (LLMs), emphasizing concerns about whether data is stored in the country of origin, and also concerns over potential US cultural dominance in AI development. The participants discussed the risks posed by slow injection of malicious code into widely used public code repositories. The participants also touched on the feedback loop in LLMs, where synthetically generated data increasingly influences AI outputs. They explored the democratization of new technologies and the balance between academic freedom and security concerns, with one extreme suggestion of not allowing those in high-risk positions to use laptops and other potentially vulnerable devices, given the inherent risks that they bring with them. They also looked at the challenges involved in ensuring that key services remain available.

The discussion then explored emerging threats, including malicious models and biased models. They discussed the threats posed by users within organizations trying to self-diagnose problems, likening it to self-diagnosis in the medical domain. The participants debated the shift in value models from data theft to data modification that goes undetected, and the changing landscape of risk-cost analysis in cybersecurity. They highlighted the potential for AI to detect security flaws while emphasizing the importance of human-based learning and insight. The discussion concluded with a recommendation to avoid being overly impressed by AI and to recognize that human cognitive intelligence remains superior to machines.

Digital Technologies
Sensor Technologies

[Chair]
Kudelski, André, President, Innosuisse - Swiss Innovation Agency; Chairman of the Board and Chief Executive Officer, Kudelski Group, Switzerland

[Speakers]
Benea-Chelmus, Ileana-Cristina, Assistant Professor of Microengineering, EPFL, Switzerland
Dario, Paolo, Professor Emeritus of Biomedical Robotics, The BioRobotics Institute, Scuola Superiore Sant'Anna - Pisa, Italy; Chief Scientist, Dubai Future Labs, Dubai Future Foundation, U.A.E.
Demotes-Mainard, Bertrand, CTO of Hardware, Thales, France
Kasmi, Chaouki, Chief Innovation Officer, Technology Innovation Institute, U.A.E.
Yano, Kazuo, Fellow, Hitachi, Ltd., Japan

Opening Remarks

The chair opened the session by emphasizing the importance of sensors in modern technology, particularly their role as the interface between the physical and digital worlds. With the acceleration of demand for AI, sensors become even more critical, since reliable data is needed to train AI models correctly, and this has become a major bottleneck in improving generative AI performance.

Kudelski, André

Following this, the speakers discussed the significance of precision metrology in both basic sciences and in industry, highlighting how precision measurements push scientific frontiers, enable new discoveries, and respond to societal demands for safety and health. The speakers emphasized the importance of atoms as the most stable and precise calibrated scale to use as a basis for measurements, linking this to the use of lasers and noting that currently the physical quantity that we can measure with the greatest accuracy is frequency, and this can be used in various ways to calculate other measurements. The

speakers pointed out that quantum sensing is based on using quantum mechanical principles to measure accurately down to the quantum limit. The speakers stressed the need for interdisciplinary collaboration to translate these advancements from laboratories to society, and to educate the next generation of engineers.

Next, the speakers discussed what is happening with new technology related to sensors. The speakers touched upon the ubiquity of MEMS, the comparative advantages of edge and cloud computing, the development of wearable and embodied sensors, new materials for sensing, silicon carbide technology, and the connection between basic and applied sciences. The speakers also highlighted the ethical and legal implications of these advancements, particularly in relation to data privacy and management.

The speakers then emphasized the critical role of sensors in mission-critical systems impacting many aspects of daily life. They also noted how sensors are essential for addressing global challenges such as climate change and energy efficiency. The speakers discussed the importance of understanding the environment in which sensors operate and the assumptions behind their use, and highlighted the trend towards distributed sensor networks and the integration of AI for more accurate and efficient sensing.

The speakers then focused on space-borne sensors and their civilian applications, pointing out how AI at the edge is revolutionizing satellite imaging for addressing global challenges like food and water security. They highlighted the use of synthetic aperture radars (SARs) and emphasized the importance of making satellite data accessible to developing countries for sustainable agriculture and decarbonization efforts.

The speakers then discussed the unexpected application of sensor technology in measuring human happiness. The speakers reflected upon people analytics, using wearable sensors to collect data on human behavior and relationships, explaining how analysis of this data reveals patterns in physical motion and social connections that correlate with happiness and productivity. The speakers emphasized the importance of understanding human happiness in the development and application of new technologies, particularly in the era of generative AI.

Discussion

Following the opening remarks, the participants engaged in a discussion. They began by touching on the risks of sensor hallucinations, analogous to AI hallucinations. The participants noted that in radar technology, false signals referred to as “angels” can occur. These phenomena require algorithms to distinguish them from actual aircraft. As the environment

changes, such as with the introduction of wind turbines and drones, sensor technology must continuously adapt to new challenges.

The discussion then shifted to the future of quantum sensors. The participants noted that while quantum technologies show great promise, they currently require highly specialized and expensive infrastructure, including cryogenics, powerful lasers, and cleanrooms. This makes them largely inaccessible to many researchers and students. The participants suggested that using sensors in everyday devices like smartphones could provide educational opportunities for students who lack access to advanced equipment, emphasizing the need to democratize these technologies.

Regarding the balance between edge and cloud computing in sensor technology, it was highlighted that while cloud computing offers advantages in terms of cost and scalability, edge computing is crucial for real-time control and applications where data privacy is a concern. The discussion touched on the need for a compromise between cloud and edge solutions, particularly in fields like healthcare that require immediate data processing and decision-making. It was noted that on-board processing could help with real-time control and adapting to changing conditions.

The participants explored the potential of combining multiple sensors with AI to enable new measurements, pointing out that hybrid data from multiple sensors, already common in technologies like GPS navigation, could be enhanced by AI to further improve accuracy and reliability. The discussion also addressed the challenges of integrating new AI technologies, particularly large language models, into existing sensor pipelines and critical systems like aviation. The importance of demonstrating reliability and liability in mission-critical systems was emphasized.

The discussion then turned to the differences between computer vision and LiDAR technologies in autonomous vehicles. The participants explained the fundamental differences in how these technologies gather and process data, with LiDAR offering potential advantages in long-range detection and resistance to hacking.

The participants then discussed the reliability and longevity of biological sensors in the human body. While progress has been made in some areas, such as glucose monitoring lasting up to two weeks, challenges remain in developing long-lasting chemical sensors. The participants then reflected on the future of metrology, questioning whether traditional precise

and expensive experiments will continue to be necessary or if data science approaches using widespread, inexpensive sensors might become more prevalent. The importance of continuing scientific research to open up new sensing possibilities, such as in different frequency bands, was highlighted.

Finally, the participants pointed out that despite the explosion in the availability of sensor devices and the rapid evolution of sensor technologies, we are still at the early stages of sensor development, and the growth of this field will continue to accelerate, creating ever increasing amounts of useful data.

Science and Technology in Society *forum* (STS *forum*)
21st Global Annual Meeting
Kyoto, Japan, October 8, 2024

Chairman's Statement

1. The 21st Global Annual Meeting of the Science and Technology in Society *forum* took place from October 6 to 8, 2024 in Kyoto, with the participation of about 1,400 global leaders in science and technology, policymaking, business, and media from over 80 countries, regions, and international organizations.

   We live in turbulent times where wars and conflicts are raging all over the planet, and never has the need for global cooperation towards peace, human security, and responding to our global environmental and social challenges been greater. Science and technology can do much to feed the hungry, heal the sick, protect the environment, and bring dignity to work, as it helps humanity get back to a sustainable development path. Thus, our discussions reviewing the key issues of our time were particularly timely.

AI

2. AI is a transformative technology with the power to revolutionize industries, enhance decision-making, and improve efficiency. However, its impact on society is twofold, bringing both benefits and challenges. While AI drives innovation, productivity, and customization, it also raises concerns about security risks, possible job displacement, economic inequality, and potential misuse. As AI continues to evolve globally, governments, societies, and businesses face growing challenges in addressing ethical and regulatory compliance. The current human-driven approach is slow, costly, and lacks consistency across jurisdictions. To navigate these complexities, there is a pressing need for automated solutions and transparent audit trails to ensure responsible AI use.

3. The rapid evolution of AI has the potential to transform the healthcare field. AI excels at managing large amounts of structured and unstructured data, extracting valuable insights to improve medical management and organizational efficiency, and facilitating real-time

interactions with healthcare providers and patients. AI offers many advantages, but it also raises societal challenges, such as concerns about hidden biases, dehumanized care, privacy issues, and the need for clear ethical and regulatory frameworks. AI is already being utilized to enhance diagnostics, monitor chronic diseases, and accelerate drug discovery. Its potential to improve the quality of care and reduce costs makes it a transformative force in healthcare.

4. AI is also challenging the traditional roles of universities in learning and discovery. To ensure that learners succeed with AI, higher education must reassess its approach, focusing on understanding and utilizing advanced technologies, interpreting data, and evaluating AI outputs. Students need to develop uniquely human skills, such as creativity, critical thinking, cultural agility, and entrepreneurship, through experiential learning. Our discussions explored how AI accelerates university research and strategies for universities to focus on impactful research while ensuring safety and ethics. With the growing need for lifelong learning due to evolving employment needs, universities should prioritize lifelong learning programs and focus on developing AI tools for personalized education.

The Digital Age

5. Scientific progress relies on rigorous verification, including peer review, reproducibility, and open data sharing. With advances in AI and deep learning, assessing the accuracy and hidden biases of new tools is crucial. Effective science communication and public engagement are essential for addressing complex issues and rebuilding trust. Particularly in the face of misinformation and disinformation, strategies to enhance trust and address cybersecurity challenges are vital. Effective, responsible science communication, outreach, and public engagement are crucial. Innovative defense mechanisms against AI- driven threats, along with international cooperation on thoughtful regulation and comprehensive policies that can fit regional realities, are emphasized as key to ensuring a secure digital environment and ethical technological advancement.

Basic Science

6. The intersection of science, innovation, and policy is at a pivotal moment now, driven by rapid advances in basic science, technology, and engineering. Key issues include how basic science and mission-driven research can coexist and interact, the evolving roles of government, philanthropy, and industry in funding basic research, and the effectiveness of international collaboration amidst new geopolitical and security challenges. Additionally, higher education institutions need to enhance their support for scientific talent while balancing their roles in entrepreneurship and societal impact, and ensure career support for emerging scientists.

Global Health

7. In an era of unprecedented global challenges, the complexity and uncertainty surrounding global health have increased as never before. Issues such as climate change, the appearance of new viruses, and antimicrobial resistance are becoming increasingly interconnected, necessitating a comprehensive and collaborative approach. The focus must be on how these global challenges are reshaping health outcomes, the strategies needed to address them, and the crucial role of international cooperation in safeguarding global health for future generations. Key issues include the interconnections between global health threats, disparities in health equity and access, and the importance of international collaboration amidst rising populism and conflict.

Biotechnology

8. In recent years, biotechnology has significantly transformed society, greatly improving human, animal, and plant health while also providing substantial economic benefits. Despite rapid technological advances, challenges remain, such as ensuring equitable access to costly personalized medicines and therapies and addressing disparities in international venture capital and research support. Harmonizing national regulatory requirements and helping academic researchers develop realistic expectations for commercialization are also crucial.

Food and Water

9. By 2050, the global population is expected to reach 10 billion, requiring a 70% increase in food production, despite a predicted 20–50% reduction in yields. Addressing this challenge will require significant transformations in agriculture to enhance productivity, minimize food losses, and optimize water use and access to safe water. Climate-smart agriculture is essential for ensuring food security, increasing productivity, and reducing agriculture's impact on the climate. The best of science, from ICT to AI, can help optimize farming techniques. And we should mobilize the new biology to explore the possibilities of novel foods and to rapidly produce plants that are drought and salt resistant, that have shorter growing seasons, along with greater yields and a higher nutritional content. All this is eminently and rapidly possible using modern biotechnology techniques,

which – despite attacks on "GMOs" – have been shown to be safe with no problems reported after more than 30 years of use. Additionally, it is important to address the impact of rising sea levels on agriculture and fisheries. There is a need for implementing early warning systems accessible to all, securing funding for loss and damage, and launching new programs focused on agriculture and adaptation.

Energy

10. The world urgently needs to achieve net-zero emissions to prevent severe environmental damage. Rising global energy demands and continued use of fossil fuels are major sources of emissions, exacerbating climate change. Effective strategies must include both removing existing CO_2 and rapidly deploying new technologies. International cooperation is essential for coordinated action and must be supported by diverse technologies and investments. Achieving the 1.5°C target by 2050 will require significant investment and innovative financing, with a crucial role for research institutions in supporting policy and investment. Strategies for integrating intermittent renewable energy, balancing grid supply and demand, and transitioning to a low-carbon, flexible grid are essential.

Climate Change

11. As countries advance in decarbonizing their economies, addressing the risks from climate change and extreme weather is crucial. These risks threaten infrastructure, socioeconomic stability, and geopolitical dynamics. Increasingly frequent and severe natural disasters, such as floods and heatwaves, impact global systems and human health, making resilience essential. Policymakers and business leaders need to confront these challenges head-on. Key discussion points included preparing infrastructure for climate hazards, utilizing tools and resources for risk management, effectively communicating climate data, fostering cross-sector collaboration, and the key role of new technologies. Adaptation strategies are particularly important for vulnerable regions facing severe impacts. Concrete measures and policies are needed to enhance resilience and support collective action for the most vulnerable populations.

Collaboration

12. Strong, effective, and global collaboration between academia, industry, and government is more crucial than ever to address major environmental and social challenges. The rapid development of mRNA vaccines during the Covid-19 pandemic demonstrated the power of such collaboration. However, the pandemic also highlighted significant inequities in vaccine access, eroded trust in institutions, and led to increased misinformation and protectionism. It is essential to strengthen cooperation, trust, and openness, with a particular focus on the Global South. Key areas for improvement include fostering trust among partners, and nurturing innovation and supporting start-ups. Improving access to primary data, and learning from past crises is necessary to better support communities worldwide.

13. Our explorations of these and other issues are far from over. We will continue our interactions and discussions to accompany the evolving lights and shadows of science and technology in the world. We look forward to convening again next year in Kyoto and have agreed to hold the 22nd Global Annual Meeting of the STS *forum* from Sunday, October 5 to Tuesday, October 7, 2025.

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- Oracle Corporation Japan
- OrganTech, Inc. * **
- Osaka Gas Co., Ltd.
- Shimadzu Corporation
- Shin-Etsu Chemical Co., Ltd.
- Sony Group Corporation
- Sumitomo Chemical Co., Ltd.
- Suntory Holdings Limited *
- Takenaka Corporation
- Tokyo Electron, Ltd.
- Toshiba Corporation
- Toray Industries, Inc.
- Toyota Motor Corporation

MALAYSIA
- Malaysian Industry-Government Group for High Technology (MIGHT)

NETHERLANDS
- Elsevier

QATAR
- Qatar Research, Development and Innovation Council

SAUDI ARABIA
- Aramco
- King Abdulaziz City for Science and Technology (KACST)

SINGAPORE
- NIPSEA Management Company Pte Ltd

SOUTH AFRICA
- Department of Science and Innovation (South Africa)

SWEDEN
- VINNOVA

SWITZERLAND
- Innosuisse *
- Kudelski Group
- Swissnex *

TAIWAN
- Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC)
- VIA Technologies, Inc.

THAILAND
- National Research Council of Thailand (NRCT) *
- Thailand Science Research and Innovation (TSRI) *

TURKEY
- Arçelik A.Ş.

U.A.E.
- Advanced Technology Research Council *

U.K.
- Cytiva

U.S.A.
- World Resources Company

American Associates of the STS forum (AA-STS)
- Bristol-Myers Squibb Company
- Chan Zuckerberg Initiative *
- Gordon and Betty Moore Foundation
- Groq *
- The Henry Luce Foundation
- IBM
- The Kavli Foundation *
- The Simons Foundation
- Thermo Fisher Scientific
- Vanderbilt University *

*New members 2023, 2024

** New membership category for Startups

Note: There is one organization not on this list

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