Some Key Areas Might See Big Breakthroughs

Driven by powerful demand and knowledge system innovation, science and technology are advancing by leaps and bounds, showing signs of transformative breakthroughs in solving some key science and technology issues. There is a good possibility that science revolution and technology revolution will take place, either successively, or in an interactive or co-existing way in the future. The S&T breakthroughs will give rise to new industries and expedite an industrial revolution, and their impact on overcoming bottlenecks of sustainable socioeconomic development might be beyond expectations.

1. Energy and resources

In terms of energy, under the pressures of both depleting fossil fuels and the demand for environmental protection, modern society will have to undergo a new round of energy source transformation and revolution. It will be a long-term process in which fossil fuels will gradually give way to nuclear power and new energy sources, leading to: the energetic development of technology for clean and efficient use of fossil fuels; the increasing percentage of nuclear power, new energy and renewable energy in the energy mix; and pilot exploitation of natural gas hydrates. In addition, there will be an overall improvement in the technology to transmit energy in an efficient, stable, secure and intelligent manner, and a complementary and systematic integration of multi-energy sources.

In terms of hydrocarbon resources, the next decade will witness the continuous upgrading of petroleum geophysics exploration technology and equipment, the prospecting of mature basins in a more precise way, improved capacity to discover potential petroleum-rich regions, and greatly enhanced recovery rates. Moreover, advanced petroleum exploration technology will see wide applications in deep oceans, Polar regions and areas with challenging geological conditions. Future exploitation will focus on unconventional petroleum deposits, such as tight oil and gas, shale gas, oil sand bitumen mines coal-bed methane and oil shale.

Regarding mineral resources, the next decade will see a deeper understanding of metallogeny in major metallogenic areas and belts, more prospecting prediction research in covered areas and the earth's deep interior, more interest in exploitation of strategic minerals such as rare earths, intensive efforts for the efficient and clean utilization of mineral resources, and more importance attached to surveys of mineral resources in oceans and polar regions.

In terms of water resources, the next decade will see a new challenge for scientific research to reveal the revolutionary laws of water resources and water complexity. The global water crisis is exacerbated by both growing demand and climate change, and involves great uncertainty and risks. Thus, more importance will be placed on studies of relationships between water resources and energy, land and grain, and ecological systems and biodiversity.

2. Materials and manufacturing

In the field of materials, science and technology for materials design and performance prediction have developed rapidly. Environment-compatible and low-cost preparation technology is given importance. Studies of techniques, processes and relationships between structure and performance are on the eve of a breakthrough. The implementation of the Materials Genome Initiative would shorten the R&D cycle. While materials research will rely more on big science facilities and research platforms, more application and development will be pursued on composite materials, bio-materials, functional materials, smart materials and the like. The progress of carbon-based electronics will accelerate the development of next-generation electronic devices such as graphene. Nano-materials will remain a research focus, and its combination with nano-fabrication, nano-evaluation and nano-characterization might bring about breakthroughs in the application of nano-biotechnology and nano-devices.

Regarding the manufacturing industry, its main trend will increasingly be "green and smart." Man-machine integration would be the basic feature of intelligent manufacturing technology. Cloud and sea computing technology will lead a new mode of information processing for manufacturing. Ubiquitous information awareness will provide new information support to intelligent manufacturing. Parallel management and visualization manufacturing technology will offer digitalized methods for manufacturing. Green technologies for process manufacturing will achieve an effective, clean transformation, and cyclic utilization of conventional and

unconventional resources will raise the comprehensive utilization rate of resources and minimize environmental impacts. Manufacturing services will offer a new approach to the upgrading and transformation of the manufacturing industry.

3. Information networks

There are many portents of dramatic changes in information technology. The integrated circuit industry is heading toward the Post-Moore Era. New functional information materials, devices and processes are mushrooming. Breakthroughs have been achieved in intelligent sensors and big data storage technologies. In terms of computers, we are gradually ushering in the Post-PC era with the decline of the Wintel platform and the rise of many other open platforms. New terminals have become household goods. The Internet will embrace the Post-IP Era, which strives to develop new generation Internet technology and overcome the limits of TCP/IP protocol. The rise of the Internet of Things and cloud technology will facilitate changes in the penetration mode, process method and application approach of information technology.

Information science and technology development in today's world features the following:

(1) Data-intensive research has become the fourth paradigm after experimental science, theoretical analysis and computing simulation. Petabyte (PB, 10^{15} bytes) data processing capacity could discover knowledge and rules from data without models and hypotheses.

(2) A cyber-physical system (human-cyber-physical ternary computing) will become the development direction of computing technology. E-People will be achieved by focusing on the computing demands of people, making comprehensive use of resources like human society (people), information space (machine) and the physical world (things).

(3) Mobile communication is heading toward "mobile broadband," with major modes such as Mobile Internet, the Internet of Things, cloud computing and sea computing.

(4) Thanks to the development of brain and cognitive science, artificial intelligence technology has regained its development momentum, with rapid progress in such fields as brain-like computers, humanoid robots, brain-machine interfaces, and brain simulation.

4. Agriculture

With the increasing pressure of grain security and growing farm product demand, agriculture S&T innovation will keep focusing on high and stable yields, safety, high efficiency and high quality. Under the mounting restraints of both resources and the eco-environment, efficient resource utilization and sustainable development will be a major research direction in this regard. With the rapid advancement of basic science in agriculture owing to significant theoretical breakthroughs in life science, agro-omics and molecular design breeding of plants and animals have become cutting-edge issues in agricultural science and technology. Owing to growing concern over the impacts of environmental and climate changes on agriculture, more importance will be place on research for disaster prevention and reduction, major disease control and low-carbon development.

5. Population and health

A brand-new understanding of human physiological and pathological processes might be reached by major theoretical breakthroughs in functional regulation of human genomes in the life process, and in particular the mechanism behind cell fate control.

With the fundamental changes in conventional medicine, health medicine will embrace a completely new development opportunity. Genome sequencing technology will be continuously renovated and its cost greatly reduced. Synthetic biological technology will break new ground for gene-therapy and bio-therapy. Stem cell and cell therapy will become the major research direction for regenerative medicine and tissue engineering. The genome-wide association study (GWAS) of human brain nerves will become a major direction for brain science. In addition, health issues and diseases due to population aging and lifestyle changes will expedite the development of modern biomedicine toward an era of "molecular regulation network of complex diseases," which calls for moving forward of the "checkpoints" for disease prevention and control. The development of new types of vaccines is a key step to address emerging and re-emerging infectious diseases. Therapeutic vaccines against cancer, metabolic and non-infectious diseases will break new ground for innovative drugs.

6. Ecology and environment

Under the guidance of addressing climate change and green economic development, worldwide changes have taken place in ecology and environment. A global eco-environment monitoring system and systematic simulation are in the pipeline, and global eco-environment research is heading toward being measurable, reportable, evaluable and dynamically simulatable. Large-scale research initiatives and platforms have been launched with biodiversity and eco-system services as its cores. Efforts have been made to find comprehensive solutions to sorting out interactive

relations among energy, food and water resources. More importance has been placed on studies of the impact of large-scale human activities on eco-systems. S&T problems raised by the objectives of global sustainable development toward 2030 will be the focus of eco-environment studies.

It is likely that breakthroughs will take place in scientific research into climate change in "hot-point" regions on the Earth, such as: changes of ice and snow in Greenland; the "ice-free Arctic" issue caused by the retreat of sea ice; the impact of a changing cryosphere on water resources, climate and the environment; and climate change in the source regions of major rivers. These will have major influences on world structure and sustainable development.

7. Space and ocean

Focusing on the Moon, Mars and asteroids, exploration of space will go deeper and further, so as to reveal the origin and evolution of the universe, the essence of dark matter and energy, and the mechanism behind solar eruptions.

Upon completion of the main body of the international space station (ISS), it is expected that new scientific knowledge and benefits will be produced continuously. Space-borne Earth observation has gradually covered all the physical parameters of various spheres of the Earth system and the impacts of human activities. It will also conduct global monitoring of greenhouse gases, and set up global research platforms so as to address global change and satisfy human needs for long-term sustainable existence and development. More importance will be attached to space situation awareness. A generally recognized code of conduct for space will be gradually set up. Space technology will tend to be more market and business-oriented.

In terms of oceans, demand will become the prime driving force. Focusing on national security and ocean rights and benefits, sustainable utilization of ocean resources and deep-sea exploration, coastal countries will place more importance on biosystem-based coastal region management systems and reach deeper and further into oceans. With the increasingly urgent demand for ocean information for coastal defense, disaster prevention and reduction, and oceanic administration, timely and comprehensive space-ocean observation has become major focus of global ocean science and technology. As deep-sea resource prospecting and exploitation heavily depend on technological development, breakthroughs in ocean science and technology will speed up the development of a new type of blue economy. The melting of Arctic sea ice will likely cause a large-scale release of methane with formidable impact on the global climate. This could make it possible to exploit petroleum resources in the region, a new theater for ocean resources competition.

8. Major frontiers of basic science and interdisciplinary studies

The intercrossing, penetration and convergence of different academic disciplines will give birth to major S&T innovation, thereby facilitating the overcoming of fundamental and bottleneck issues in many disciplines. Therefore, many new features will be observed.

The unfolding of the mystery of dark matter and dark energy would lead to a transformation of physics. Particle physics would see new breakthroughs. Quantum studies would develop from the phase focusing on observation explanation toward a stage centering on manipulation, ushering in a "regulation era." Breakthroughs in molecular biology, synthetic biology and "artificial life" would open new ground for understanding the origins and evolution of life. Studies of human brain and its cognitive function and the essence of intelligence will speed up. Theories and methodologies of basic sciences such as mathematics, physics, biology and chemistry, and their integration with other disciplines will continue to be a main theater for interdisciplinary studies. Integration of information science, technology with life science, brain science and other fields will be new frontiers with impact on research paradigms.