Deciphering the Structure of the U.S.-China Conflict over Science and Technology

— On the Trends in China's Science and Technology —

(U.S.-China Relations Study Group Commentary No. 9)

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1. China's Breakthrough Shown by Science and Technology Indicators

The results of science and technology are published in the form of academic papers. The number of published papers is an extremely powerful indicator of a country's scientific and technological capabilities. Until around the year 2000, the number of papers published in China was only about one-sixth of that in the U.S. However, according to data from the Dutch publisher Elsevier B.V.'s Scopus database of papers and the U.S. National Science Foundation (NSF), China surpassed Japan in 2004 and finally overtook the U.S. to take the top spot of published papers in 2018. Extrapolating the rate of increase, there is no doubt that the gap between China and the U.S. in terms of numbers will widen in the future.

Not a few Japanese researchers think that papers written by Chinese researchers are "all junk papers." Japan tends to underestimate China's scientific and technological capabilities. However, even in terms of the "citation index," which indicates the importance of papers, Chinese researchers have made remarkable strides in their achievements. According to the "Highly Cited Researchers" report by Clarivate Analytics, the number of authors who wrote extremely high-profile papers with "1% citation index" reached 770 in China, second to 2,650 in the U.S., or around one-third of that in the U.S. In 2015, about five years ago, China ranked fourth after the U.S., the U.K., and Germany, with only about one-tenth the number of researchers compared to the U.S. (Table 1)

In terms of the universities and research institutes to which the authors of important papers belong, the Chinese Academy of Sciences and Tsinghua University rank second and ninth, respectively. Unfortunately, Japan is not in the top 10. Neither The University of Tokyo nor RIKEN research institute is regarded as top-notch. (Table 2)

Table 1 Countries and Regions Ranked by Number of *h*-index Authors (highly-cited authors with 1% citation index) (2020)

Rank	Country	No. of authors
1	U.S.	2,650
2	China	770
3	U.K.	514
4	Germany	345
5	Australia	305
6	Canada	195
7	The Netherlands	181
8	France	160
9	Switzerland	154
10	Spain	103

Table 2 Institutions Ranked by the Number of Authors of Important Papers

Rank	University/research institute	Country/region	No. of authors
1	Harvard University	U.S.	188
2	Chinese Academy of Sciences	China	124
3	Stanford University	U.S.	106
4	National Institute of Health (NIH)	U.S.	103
5	Max-Planck-Institute	Germany	70
6	University of California, Berkeley (UCB)	U.S.	62
7	Broad Institute	U.S.	61
8	University of California, San Diego (UCSD)	U.S.	56
9	Tsinghua University	China	55
10	University of Washington	U.S.	54

China tops the list in other indicators of scientific and technological capability, such as "research and development expenditure," "government budget for science and technology," "number of researchers," and "number of international patent applications." In particular, it is no exaggeration to say that the rate of growth since 2000 has been accelerating. It is likely that Chinese universities will eventually be ranked in the top 10 in the university rankings as well. The Chinese government's Double First-Class University Plan aims to create top-notch universities and faculties.

It was in 1985 that this author first visited universities and research institutes in China. The universities in Beijing, Xian, and Shanghai all had very little basic infrastructure. It was astonishing to see the researchers make their own experimental equipment and conduct research. The reactors at the China Institute of Atomic Energy (CIAE) looked about the same as the criticality experimental equipment at Japanese universities.

Today, when we consider the quality and quantity of basic science, China has surpassed the U.S., at least in terms of quantity. Mr. Hayashi Yukihide, former Deputy Minister of Education, Culture, Sports, Science and Technology of Japan who has continued to survey trends in science and technology in China, says, "Logically, no matter how many things of poor quality are collected, the quality will not be higher because of the quantity, but when the numbers are as high as they are in China, I have the feeling that perhaps the quality may be higher because of the quantity" (J+C Economic Journal, July 2018). As Mr. Hayashi points out, the scope of basic science in China is expanding greatly, and the time may soon come when it will turn into quality and produce Nobel Laureates. (Table 3)

Table 3: Chinese Nobel Prize Laureates in the Three Natural Sciences

Year Awarded	Nobel Laureate	Field	Background
1957	Chen Ning Yang Yang Chen-Ning	Physics	The National Southwest Associated University, China; moved to the U.S.
1957	Tsung-Dao Lee Lee Tsung-Dao (T.D.)	Physics	The National Southwest Associated University (in China); moved to the U.S.
1976	Samuel C.C. Ting (Ting Chao Chung)	Physics	Born in the U.S.; his parents moved from Taiwan to study in the U.S.
1986	Lee Yuan T.	Chemistry	National Tsing Hua University, Taiwan; moved to the U.S.

1997	Steven Chu	Physics	Born in the U.S.; his father, a former U.S. Energy Secretary, studied in the National Southwest Associated University, China
1998	Daniel C. Tsui	Physics	Born in Henan Province, China; moved to Hong Kong, then to the U.S.
2008	Roger Y. Tsien (Roger Yonchien Tsien)	Chemistry	Born in the U.S.; nephew of Tsien Hsue-shen
2009	Charles K. Kao (Charles Kuen Kao)	Physics	Born in Shanghai; moved to Hong Kong, then to the U.K.
2015	Tu Youyou	Physiology or Medicine	Department of Pharmacology, Peking University, China

Of course, China also has its weaknesses. Its strengths are rapid decision-making by the Communist Party of China (CPC), ample R&D funding, and human resources; however, the lack of free will among researchers, the dual structure of research institutions and universities, the bias toward priority fields and the neglect of other research areas, the subordination of originality, and the lack of ideals in science and technology such as the quest for truth and contribution to humanity will be long-term weaknesses. China's science and technology policy, which solely aims for the country to become a science and technology powerhouse, may be subject to various contradictions in the future.

2. The U.S. and China Competition in Space Development

Along with scientific and technological indicators, space development shows the true strength of a country. In particular, now that space has become a "War-Fighting Domain," it has also become an important indicator for national security. Both the U.S. and China recognize that "whoever controls space controls everything." China launched its first satellite on April 24, 1970, during the Cultural Revolution. It was only two months after the launch of Japan's first satellite, OHSUMI. Today, 50 years later, China aims to become a "space power" and is closing in on the U.S., which had an overwhelming advantage.

On May 15, 2021, the 100th anniversary of the founding of CPC, China's (Mars surface) rover Zhurong released from the (Mars) rover Tianwen 1 successfully landed on the surface of Mars. Previous to that, on February 19, 2021, the U.S. Mars rover Perseverance had arrived on Mars. Compared with lunar exploration, Mars exploration is significantly more difficult. Russia has launched nearly 30 Mars probes since 1960, but they have all failed. Japan also launched the explorer NOZOMI in 1998, but it failed because communication was lost midway.

The U.S. has also attempted to go to Mars since the launch of Mariner 3 in 1964, but Viking 1 in 1976 was the first to succeed in a soft landing. The distance to Mars is about 75 million kilometers, about 200 times the distance between the Moon and Earth. In addition, there are many technical hurdles to overcome, such as injection into orbit, orbit, and soft landing of the rover, and it was even said that “there is a graveyard of rovers between Earth and Mars.” China succeeded in its first attempt to explore Mars, a feat that took the U.S. more than a decade to achieve. The next goal is to collect and return samples from Mars. Manned flight is an extremely high hurdle because it will take nearly a year to complete the mission, and the earliest it can be accomplished is around 2050. (Table 4)

Table 4: Trends in China’s Space Development

Year	Item/Event
1999	Successful launch of spacecraft Shenzhou 1 on the 50th anniversary of the founding of the People’s Republic of China.
2003	Successful launch of Shenzhou 5 with astronaut Yang Liwei on board.
2007	First lunar probe Chang’e 1 reached lunar orbit.
2011	Successful launch of the Tianwen 1 space station.
2013	Successful soft landing of Chang’e 3 on the Moon.
2016	Successful launch of quantum communication satellite Mozi.
2019	Successful soft landing of Chang’e 4 on the far side of the Moon.
2020	Successful lunar sample return by Chang’e-5; completion of BeiDou Navigation Satellite System.
2021	Successful soft landing of Tianwen 1 on Mars on the 100th anniversary of the founding of CPC.

2022	China's Tiangong space station to be operational.
Early 2030s	Manned space flight to the Moon.
2049	100th anniversary of the founding of the People's Republic of China.
around year 2050	Manned space flight to Mars.

China has already surpassed the U.S. and Russia in the number of satellite launches. China has also made remarkable progress in the field of space utilization from the Earth to geostationary orbit (GEO). While the U.S.-led International Space Station (ISS) will be decommissioned in 2024, China's version of the space station, Tiangong, will begin operations in 2022. In June 2021, three astronauts arrived at Tiangong and have been engaged in extravehicular and other activities. The U.S. Congress is considering extending operations of the ISS to 2030, but it is highly likely that China will be the sole proponent of low-orbit weightless space experiments.

In terms of satellite positioning systems, the BeiDou (Navigation Satellite System) could replace the Global Positioning System (GPS). In June 2020, China completed a satellite navigation system with 35 BeiDou-3 satellites and launched positioning, navigation, and timing (PNT) services. More than 30 countries and regions involved in "One Belt One Road Initiative (now referred to as the Belt and Road Initiative, or BRI)" are already using the system. Qualcomm's mobile chips for cell phones in the U.S. and the iPhone also have the function. In addition to GPS, Europe operates Galileo, and Russia operates GLONASS as satellite positioning systems. The accuracy of BeiDou will be upgraded to centimeter-level in some countries and regions, giving it an advantage over other positioning systems that are measured in meters.

In the field of space communication, China's quantum communication satellite Mozi is unique. Quantum communication, which sends encrypted messages, has a current reach of only around 100 kilometers between users on the ground. However, by connecting the ground and outer space, Mozi, launched in 2016, succeeded in the world's first quantum teleportation of 7,600 kilometers. In January 2021, China built a quantum communication network covering 32 points, including Beijing and Shanghai. Professor Pan Jianwei of University of Science and Technology of China, who is leading the development of this technology, is called the "Father of Quantum" and known as the Chinese researcher closest to winning the Nobel Prize. Professor Pan says, "If quantum networks are built around the world, cybersecurity concerns will disappear."

The U.S. and China are also competing in manned flights to the Moon. The U.S. achieved the first lunar landing with Apollo 11 in 1969, but the Apollo program ended in 1972, and the U.S. and China are battling to achieve the first manned lunar landing (MLL) in the 21st century. The landing on the far side of the Moon by China's 2018 launch of Chang'e 4 has inspired the U.S. This is because water is expected to be present in craters near the south pole on the far side of the Moon and China is one step ahead in the space race to get to the water. Water is not only necessary to sustain life, but can also be used as an energy source by being broken down into oxygen and hydrogen. In March 2019, U.S. Vice President Mike Pence exposed the rivalry, saying, "China was the first to reach the far side of the moon last year and has made clear its ambition to gain a strategic position on the moon and become the world's preeminent 'space power.'"[1]

Chang'e 5, the successor probe to Chang'e 4, also successfully collected 1,731 grams of lunar soil in December 2020. Unmanned sample collection is extremely difficult, and Chang'e 5 is the second spacecraft after Russia to have succeeded. The U.S. is planning to send two astronauts, a man and a woman, to the Moon in 2024 under its Artemis program. Both the U.S. and China are hurrying to develop giant rockets with the aim of landing a man on the Moon for the first time in the 21st century. The development of the Space Launch System (SLS) by the U.S. National Aeronautics and Space Administration (NASA) has been delayed, so the plan for 2024 is estimated to be significantly delayed. Meanwhile, China is developing a giant rocket, the Long March 9 (CZ-9). The engine is a 500-ton class liquid oxygen kerosene engine developed by No. 6 Research Institute of the China Aerospace Science and Technology Corporation (CASC), but the information about it has been missing since the successful test of the first stage engine was reported in March 2019. The U.S. is one or two steps ahead of China in manned flights to the Moon, but China is also aiming to achieve this goal in early 2030.

[1] China launches first astronauts to its new space station, as race with U.S. heats up, *The Washington Post*; June 17, 2021

3. The Novel Coronavirus Pandemic and Digital Transformation

It has been a long time since the word “ubiquitous” began to be used, but “ubiquitous” is an apt description of today’s China. This is because around 1.2 billion people, or about 90% of the country’s 1.4 billion people, are connected via the Internet. Not just mobile payments like Alipay and WeChat Pay are ubiquitous. Shopping, social networking systems, transportation, car distribution, logistics, education, gourmet food, delivery, news, digital contents, games, events, and all other services in society are provided through the Internet. In 2015, China’s Premier Li Keqiang proposed “Internet Plus” plan, which has literally added all services to the Internet. Not only Alibaba and Tencent, but also other giant platforms were born one after another.

The most important digital transformation (DX) is happening in the medical and healthcare sectors. The Health Code app has been developed by the Alibaba Group as a contact tracing app to control the Novel Coronavirus infection (COVID-19) pandemic. The system has now become an infrastructure more indispensable to social life than mobile payment. People have learned firsthand how much more important health is than money, which is the reason why China has been able to control COVID-19 today. The Health Code also records vaccination information, and has become an indispensable information infrastructure not only for shopping and using public transportation, but also for getting to and from work.

In the medical and healthcare sectors, all sorts of advanced technologies have been introduced, including artificial intelligence (AI), robotics, drones, and 5G. In AI-based CT imaging diagnosis, an AI engine processed the diagnosis of pneumonia, which normally takes doctors 30-40 minutes, in just 20 seconds. Some of these products have landed in the Japanese market. A wealth of medical data is ideal for improving the accuracy of AI diagnosis. Online medical treatment is also spreading rapidly, and even online surgery has been performed, albeit on a trial basis. The number of base stations for 5G, the next-generation communications network that will support this technology, has already exceeded one million, and the number of compatible smartphones shipped has exceeded the level of 300 million.

With “non-contact” as the keyword, disinfection robots, food delivery robots, patient transport robots, temperature detection robots, and PCR testing robots have been developed, and the world of medical service robots has blossomed. Disinfection robots and food delivery robots have been imported to Japan.

The Chinese government is deploying the Skynet surveillance system that can authenticate its 1.4 billion citizens in one second. A total of 600 million surveillance cameras with facial recognition functions have been deployed across the country and are connected to supercomputers through a 5G network, to identify individuals by comparing them with data from their ID cards. The Western media tends to label this as a "digital dystopia" because the information and actions of individuals are completely exposed. However, things are not so simple. After all, DX has made people feel safe, secure, and has made life more convenient.

The latest news that surprised this author was the establishment of Brain Machine Interface (BMI) ventures. The BMI technology enables implant of a chip in the brain to provide treatment and to control memory and sleep, which poses a major ethical problem. In Japan, there is not even a code of ethics for BMI because it is reminiscent of lobotomies. In China, two venture companies have already raised funds and embarked on commercialization. We should keep an eye on this activity to see where China's DX ends up.

4. The Geopolitics of Science and Technology and Japan's Position

Science and technology are often combined when discussed, but science and technology are fundamentally different. While science aims to be original, technology begins with imitation. China is building itself into a science and technology powerhouse by introducing cutting-edge technologies from developed countries, imitating and researching them, and producing them domestically. Although illegal technology acquisition is a criminal offense, it is a standard method of catching up in the technological field.

On the other hand, the U.S. is setting almost all advanced technologies subject to regulations on the grounds of "security threat." However, all science and technology are basically global and dual-use, and it is nearly impossible to bind them by laws and/or systems. There is no other way to compete with science and technology than to strengthen scientific and technological capabilities. (Table 5)

China's development in the field of science and technology will continue for a long time to come. This is because China is the world's largest source of high-level human resources, and it is unlikely that the abundance of human resources and funds, as well as the strong will of the CPC to become a "science and technology powerhouse," will waver. Moreover, the struggle for supremacy between the U.S. and China over science and technology is likely to continue for quite a long time. It is hard to imagine that China will compromise in the run-up to the centennial of the founding of the nation in 2049. On the other hand, the U.S. hardline policy toward China does not vary according to political party; therefore, it cannot be expected that the U.S. would ease the policy with the change of administration between the Democrats and Republicans. If the view that this is a struggle for supremacy between the regimes of communism and classic liberalism takes hold, a second Cold War will become a reality.

Table 5: 14 Cutting-edge Basic Technologies Regulated by the U.S.

1	Biotechnology	Synthetic biology, neurotechnology, etc.
2	Artificial intelligence and machine learning	Genetic computing, etc.
3	Positioning, navigation, and timing technology	
4	Microprocessor	System-on-chip
5	Advanced computing	Memory-intensive logic
6	Data analysis technology	Visualization technology, automatic analysis algorithms
7	Quantum information, quantum sensing	Quantum computers, quantum cryptography, etc.
8	Logistics technology	Portable power equipment/device, etc.
9	Additional manufacturing technology	3-dimensional (3D) technology
10	Robotics	Microdrones, microrobotics
11	Brain-computer interface	Brain machine, etc.
12	Supersonic technologies	Flight control algorithms
13	Advanced materials	Functional fibers, biomaterials, etc.
14	Advanced monitoring technology	Facial recognition, voice recognition, etc.

Furthermore, the decline of science and technology in Japan is expected to continue for quite some time. With the declining birthrate and aging population, the worsening financial situation of the government, the exhaustion of private sector vitality, and the decrease in the number of young researchers, there are no favorable factors for Japan to make a V-shaped recovery in the field of science and technology in the near future.

Japan is an ally of the U.S. and both a rival and a partner of China. Is there really a way to halt Japan's decline in the midst of the U.S.-China confrontation? In an interview, Nobel Laureate and President of Science Council of Japan, Kajita Takaaki, Professor Emeritus and Distinguished Professor at The University of Tokyo, once said, "Japan is not moving toward becoming a nation of science and technology," and asked, "What kind of nation is Japan aiming to become? If it is not science and technology, then show us what it is."

Fortunately, Japan still has an abundance of original research results and technological seeds that hold high expectations for innovation. This author believes that the only way to gain a firm position in the complicated international situation is for Japan to rebuild itself to achieve a bright future as a "Science and Technology Nation."

November 10, 2021
This is an English translation of the original Japanese-language NPI Commentary posted on the NPI Japanese website on August 26, 2021.