

Implementing the “Pioneering Action” Plan to Promote Leapfrog Development of Science and Technology: Postprint on Major Scientific and Technological Achievements of the Chinese Academy of Sciences Since the 18th National Congress of the Communist Party of China

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Abstract

Since the 18th National Congress of the Communist Party of China, the Chinese Academy of Sciences (CAS) has, in accordance with the “Three Orientations” and “Four Leads” requirements proposed by President Xi Jinping for CAS, deeply implemented the “Pioneering Action” Plan and comprehensively advanced reform, innovation, and development. This has yielded remarkable achievements across all endeavors, creating a dynamic landscape characterized by the continuous emergence of innovative talents, innovative achievements, and innovative highlights. CAS has led and propelled the leapfrog development of science and technology in China, making significant contributions to implementing the innovation-driven development strategy and building an innovative nation. This article introduces CAS’ s adherence to the “Three Orientations” from 2012 to 2017, its focus on delivering major scientific and technological achievements, its continuous enhancement of independent innovation capabilities, and its acquisition of a number of major original achievements that have attracted worldwide attention, with particular emphasis on 20 landmark major achievements over the five-year period. The article concludes by elaborating on CAS’ s overall vision and initiatives to further promote the output of major achievements.

Full Text

Implementing the “Pioneer Initiative” to Promote Leap-forward Development of Science and Technology: Major Scientific and Technological Achievements of the Chinese Academy of Sciences Since the 18th CPC National Congress

Chinese Academy of Sciences

Since the 18th National Congress of the Communist Party of China, the Chinese Academy of Sciences (CAS) has diligently followed General Secretary Xi Jinping’s requirements of “Three Orientations” and “Four Firsts,” thoroughly implemented the “Pioneer Initiative” plan, and comprehensively promoted reform and innovative development. These efforts have yielded remarkable achievements, creating a dynamic landscape characterized by the emergence of innovative talents, groundbreaking results, and vibrant scientific highlights. CAS has led and propelled the leap-forward development of science and technology in China, making significant contributions to implementing the innovation-driven development strategy and building an innovative nation. This article introduces how CAS, adhering to the “Three Orientations” between 2012 and 2017, focused on producing major scientific and technological achievements, continuously enhanced its capacity for independent innovation, and attained a series of world-renowned major original achievements, with particular emphasis on 20 landmark accomplishments over the five-year period. The article concludes by elaborating on CAS’s overall thinking and measures for further promoting major achievements.

Keywords: Chinese Academy of Sciences (CAS), Pioneer Initiative Action, remarkable achievements of science and technology

1. Significantly Enhanced Capacity for Major Achievements Output

CAS has substantially improved its ability to deliver major scientific and technological results. Among the top 25 government research institutions globally, CAS is China’s only listed institution, ranking 11th—five positions higher than in the inaugural 2016 ranking. According to the Nature Index, an internationally recognized metric for measuring basic research impact, CAS has topped global comprehensive rankings for five consecutive years among all organizations including universities, government research institutions, enterprises, hospitals, and NGOs.

Between 2012 and 2017, CAS adhered to the “Three Orientations,” concentrated on producing major scientific and technological achievements, continuously enhanced its independent innovation capabilities, and delivered a batch of world-renowned major original achievements, achieving a historic shift from

primarily following to running alongside and leading in some major innovation fields. General Secretary Xi Jinping mentioned six major scientific and technological achievements from the past five years in his report to the 19th CPC National Congress, among which “Tianyan” (FAST), “Wukong,” and “Mozi” were completed by CAS, while CAS played key roles in “Tiangong” and “Jiaolong.” CAS also contributed to the new materials R&D for “Large Aircraft” and provided important scientific and technological support for “South China Sea Reef Construction.”

Among the “2016 Top Ten Scientific Advances in China” released by the Ministry of Science and Technology, seven were led or participated in by CAS. Among the “2016 Top Ten Science and Technology News Items in China” selected by academicians of the Chinese Academy of Sciences and Chinese Academy of Engineering, eight were led or participated in by CAS. As first completer or first completion unit, CAS received 78 National Natural Science Awards, accounting for 34.7% of the national total, including three first prizes (out of four nationwide). CAS also received seven first prizes for Technical Invention Awards and special/ first prizes for Scientific and Technological Progress Awards. Over the past five years, three CAS academicians—Zheng Zheming, Zhang Cunhao, and Zhao Zhongxian—have received the State Supreme Science and Technology Award. In November 2017, Clarivate Analytics released its list of 2017 Highly Cited Researchers, with 55 CAS individuals selected, ranking CAS third among global scientific and educational institutions.

Due to these world-leading achievements, several outstanding scientists have received important international science and technology awards on behalf of China for the first time, demonstrating China’s enhanced international scientific and technological influence. For example, Academician Wang Yifang received the 2015 Breakthrough Prize in Fundamental Physics (the first Chinese scientist to receive this award), Academician Zeng Qingcun received the 2016 International Meteorological Organization Prize (the highest award in meteorology), and Academician Yao Tandong received the 2017 Vega Medal (equivalent to the Nobel Prize in geography, making him the first Asian scientist to receive this award). Academician Pan Jianwei was selected as one of *Nature’s* 2017 Top Ten Global Science Figures for “leading China to become a leader in long-distance quantum communication technology.”

Focusing on supporting the “Belt and Road” Initiative, CAS has established nine overseas science and education bases, achieving a breakthrough for Chinese research institutions establishing overseas branches. It has also founded the Alliance of Academies of Sciences along the “Belt and Road”—China’s first substantive, comprehensive international science and education organization—and made outstanding contributions to technologically supporting the construction of the China-Pakistan Economic Corridor.

Through integration of science and education to cultivate innovative talents, CAS has delivered a large number of high-level talents to society, making positive contributions to building a talent-strong nation. Over the past five years,

CAS has conferred more than 70,000 degrees of various types, including 29,000 doctoral and 34,000 master's degrees. Currently, there are 75,000 enrolled students, including 67,000 graduate students. Additionally, CAS has trained 800 students from countries along the "Belt and Road."

Over the past five years, the transfer and transformation of CAS scientific and technological achievements have enabled social enterprises to add 1.7 trillion yuan in sales revenue and 228.9 billion yuan in profits and taxes. CAS-affiliated enterprises have achieved 1.7 trillion yuan in operating revenue, paid over 45 billion yuan in taxes, and provided 150,000 jobs. For example, the tumor immunotherapy drug from Shanghai Institute of Organic Chemistry, CAS, achieved single-item transformation benefits of \$457 million. Siasun's mobile robots hold the world's largest market share, and iFLYTEK ranked sixth in MIT Technology Review's list of "50 Smartest Companies."

2. Continuous Emergence of Landmark Major Achievements

Over the past five years, CAS has advanced to the international advanced or leading ranks in frontier fields including iron-based high-temperature superconductivity, quantum communication, neutrino oscillation, advanced nuclear energy, stem cells and gene editing, and artificial intelligence. In major strategic areas such as deep space, deep sea, deep earth, cyberspace security, and defense technology innovation, CAS has broken through a batch of key core technologies. In robotics and intelligent manufacturing, new materials, new drug creation, clean and efficient coal utilization, agricultural technology innovation, resource ecology and environment, and disaster prevention and mitigation, a batch of major scientific and technological achievements and transformation demonstration projects have taken root and yielded remarkable economic and social benefits.

These major innovative achievements demonstrate China's rapidly developing scientific and technological strength and innovation capabilities, highlight China's contributions to global scientific and technological development, unprecedentedly boost China's scientific community's innovation confidence, unprecedentedly stimulate society's innovation enthusiasm, and unprecedentedly open broad prospects for building a world science and technology powerhouse. They provide powerful momentum and strong support for China to comprehensively build a moderately prosperous society and realize the Chinese Dream of the great rejuvenation of the Chinese nation.

2.1. Facing the World's Scientific and Technological Frontiers (1) Comprehensive International Leadership in Quantum Communication. The world's first quantum science experimental satellite, "Micius," successfully achieved three major scientific goals at the thousand-kilometer level: star-to-ground two-way quantum entanglement distribution, star-to-ground quantum key distribution, and ground-to-star quantum teleportation, representing a milestone achievement. "First realization of quantum teleportation with multiple degrees of freedom" was ranked the top of the ten major breakthroughs

in physics in 2015. The construction of the fiber-optic quantum secure communication backbone network, the “Beijing-Shanghai Trunk Line,” achieved the world’s first intercontinental quantum communication. Quantum communication equipment has provided information security guarantees for major Party and state activities.

(2) Historic Breakthroughs in Quantum Computing. Building on the international first realization of ten-photon entanglement manipulation, CAS independently developed the world’s first single-photon quantum computer, laying a solid foundation for China to achieve its goal of “quantum leadership.”

(3) Commissioning of “China’s Eye” (FAST). This is the world’s largest single-aperture and most sensitive 500-meter aperture spherical radio telescope, providing unique means for exploring cosmic mysteries and offering a world-leading innovation platform for basic research, strategic high-tech development, and international scientific and technological cooperation. It was completed and commissioned in September 2016, with General Secretary Xi Jinping sending a congratulatory letter. [FIGURE:N] On August 22 and 25, 2017, two pulsars were discovered successively, with their parameters validated through international certification.

(4) Major Scientific Discoveries from the Dark Matter Particle Detection Satellite. “Wukong” is by far the world’s space detector with the widest observation energy range and optimal energy resolution. It has successfully obtained the highest-precision high-energy electron cosmic ray energy spectrum internationally, and related detection and research results are expected to become groundbreaking discoveries in particle physics and astrophysics, promoting major breakthroughs in humanity’s exploration of cosmic mysteries.

(5) Series of Major Breakthroughs in Condensed Matter Science Reaching Internationally Leading Levels. Iron-based high-temperature superconductor discovery and physical property research have achieved breakthrough progress. CAS first discovered Weyl fermions, first discovered topological semimetal states, first observed triple-degenerate fermions, and discovered pure Majorana zero modes in iron-based superconductors. In collaboration with Tsinghua University, CAS experimentally observed the quantum anomalous Hall effect for the first time internationally.

(6) China’s Space Science Research Entering the World’s Front Ranks. CAS independently developed and successfully launched China’s first retrievable microgravity scientific experimental satellite “Shijian-10,” the world’s first carbon satellite, and the world’s highest-sensitivity and highest-resolution hard X-ray telescope “Insight” and other space science experimental satellites, achieving a batch of major scientific discoveries and experimental verification results. For example, “Insight” successfully monitored the burst sky area of the first binary neutron star merger gravitational wave event, making important contributions to global gravitational wave observation and research.

3. Facing Major National Needs

(1) Breaking Through Key Core Technologies in Manned Spaceflight and Lunar Exploration Programs. In the rendezvous and docking of “Shenzhou-10” and “Tiangong-1,” CAS led the completion of space application system development tasks. In the rendezvous and docking of “Shenzhou-11” and “Tiangong-2,” CAS led the completion of all 14 scientific experiments in three major scientific fields. In the “Chang’e” series missions, CAS completed key tasks including ground applications, payloads, and Very Long Baseline Interferometry (VLBI), playing an important role in the complete success of the projects. Among the eight scientific instruments on the “Chang’e-3” rover, seven were developed by CAS.

(2) China’s Deep-Sea Scientific Exploration Advancing into the Ten-Thousand-Meter Era. The independently developed ten-thousand-meter remotely operated vehicle “Haidou” conducted China’s first comprehensive ten-thousand-meter abyss scientific expedition in the Mariana Trench Challenger Deep, completing multiple ten-thousand-meter depth diving operations (maximum depth 10,911 meters) and obtaining batch precious samples and data. In September 2017, China’s first independently developed 6,000-meter-class deep-sea scientific research remotely operated vehicle completed a diving depth of 5,611 meters, setting a new national record for remotely operated vehicles. [FIGURE:N]

(3) Playing a Key Role in “Jiaolong” Manned Submersible Development. CAS completed two of the three internationally leading technologies in “Jiaolong” (acoustic system and control system). The successful development of “Jiaolong” marked China’s entry into the ranks of advanced manned deep-diving nations, enabling it to play a pioneering role in deep-sea mineral resource exploration and deep-sea scientific research.

(4) Making Important Contributions to the “BeiDou” Satellite Navigation System Global Network. As a major construction unit, CAS undertook key tasks for “BeiDou-2,” global system test satellites, and “BeiDou-3,” independently developed and successfully launched the first new-generation “BeiDou” global system satellite, with key single units and components such as satellite-borne atomic clocks achieving domestic application, providing reliable guarantees for high-precision navigation, positioning, and timing services.

(5) Series of Major Breakthroughs in New-Generation Information Technology. Quantum communication technology, Cambrian deep neural network processors, and “Industry 4.0” intelligent manufacturing solutions (jointly developed with German SAP) were selected for the third World Internet Conference Leading Scientific and Technological Achievements. Key core technologies in high-performance computing, artificial intelligence, and cloud computing have been broken through.

(6) Continued International Leadership in Advanced Nuclear En-

ergy Research. The fully superconducting tokamak (EAST) created a world record for China's magnetic confinement fusion research in hundred-second-scale steady-state high-confinement mode operation. CAS originally proposed the accelerator-driven advanced nuclear energy system solution and built a prototype, which can increase uranium utilization from the current less than 1% to over 95%, reduce processed nuclear waste to less than 4% of spent fuel, and shorten radioactive lifetime from hundreds of thousands of years to about 500 years. CAS is also a major international research force in thorium-based molten salt reactor system key technologies.

(7) Independent Development of the World's First Deep Ultraviolet Solid-State Laser Source Frontier Equipment. This marks China as the world's only country capable of manufacturing practical and precision deep ultraviolet all-solid-state lasers, and has built a complete system from materials, devices, and instruments to applications, with related scientific research reaching internationally leading levels.

(8) Ultra-Intense Ultra-Short Laser Research Reaching Internationally Leading Levels. Following the August 2016 achievement of 5-petawatt world peak power laser pulse output, the ultra-intense ultra-short laser experimental device made major progress again in October 2017 by achieving 10-petawatt world highest power output (1 petawatt equals 10^{15} watts, equivalent to 500 times the average power of the global power grid). This achievement will promote the development of related strategic high technologies and trigger new technological revolutions and new industries.

4. Facing the Main Battlefield of the National Economy

(1) Industrialization of Clean Energy Core Technologies. The "high-temperature iron-based slurry-phase bed coal indirect liquefaction technology" was successfully applied in the Shenhua Ningxia 4-million-ton/year coal-to-liquids plant, with General Secretary Xi Jinping sending a congratulatory letter, marking China's independent mastery of internationally leading core technologies. Methanol-to-olefins technology achieved world-first industrial production with world-leading technical indicators, forming a production capacity of 6.5 million tons/year.

(2) Milestone Major Principle Breakthrough in Direct Coal-to-Olefins via Coal Gasification. This overturns the water-gas shift model with high water and energy consumption that has dominated the international coal chemical industry for over 90 years. It directly uses the mixed gas produced by coal gasification to obtain low-carbon olefins with high selectivity, establishing a new low water-consumption coal conversion pathway in principle and providing new thinking for China's coal chemical industry development.

(3) Ending China's High-Precision Large-Scale Grating Manufacturing Constraints. The independently developed large high-precision diffraction grating ruling system has ruled the world's largest area echelle grating (400 mm

× 500 mm), bringing China's related precision mechanical processing capabilities to internationally leading levels and providing key core technological support for the competitiveness of China's related high-tech fields and spectroscopic instrument industry.

(4) Agricultural Science and Technology Innovation Achieving Remarkable Economic and Social Benefits. Jointly with the Ministry of Science and Technology and four provinces/municipalities (Shandong, Hebei, Liaoning, and Tianjin), CAS organized and implemented the “Bohai Granary” saline-alkali land medium-low yield field transformation science and technology demonstration project, establishing 36 core demonstration bases in 27 counties and cities, with an expected annual increase of 10 billion jin (5 billion kg) by 2020. CAS also built marine ecological ranch demonstration bases in Shandong and conducted ecological grass-livestock industry trial demonstrations in Inner Mongolia. CAS bred new high-yield and high-quality crop varieties of rice, corn, wheat, and soybeans, opening new paths for improving breeding efficiency. The recently developed new rice germplasm “Giant Rice” can reach 2.2 meters in plant height and over 800 kg per mu yield, featuring lodging resistance, pest and disease resistance, and flood tolerance, representing a new breakthrough in rice research.

(5) Series of Major Breakthroughs in Life Sciences Research. Stem cell and regenerative medicine research ranks among the world's leading ranks, with clinical applications in repairing uterine endometrium and spinal cord injuries. CAS first established the CRISPR gene editing technology system in rice and wheat, obtaining the world's first gene-edited plant; created the world's first gene-edited crab-eating macaque. CAS was the first internationally to reveal the Ebola virus invasion pattern of human cells; independently developed new anti-Alzheimer's oligosaccharide drugs; mastered advanced heavy ion cancer therapy technology and independently designed and built a demonstration device.

(6) Providing Key Scientific and Technological Support for Ecological Civilization Construction. Jointly with the Ministry of Environmental Protection, CAS organized and carried out a remote sensing survey and assessment of national ecological environment changes from 2000 to 2010, providing scientific basis and technical methodology systems for China's ecological protection red line demarcation and related institutional development. CAS organized scientific assessments of environmental changes on the Qinghai-Tibet Plateau, providing scientific and technological support for optimizing the construction of the plateau's ecological security barrier system. In August 2017, the second comprehensive scientific expedition to the Qinghai-Tibet Plateau was officially launched, with General Secretary Xi Jinping sending a congratulatory letter.

5. Further Thinking and Measures for Promoting Major Achievements

Entering the new era, CAS will, under the guidance of Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era and under the leadership of the Party Central Committee and the State Council, follow General Secretary Xi Jinping's requirements of "Three Orientations" and "Four Firsts," accelerate the implementation of the "Pioneer Initiative" plan, take major achievements output as the orientation, strive to achieve leap-forward development of science and technology first, act as a pioneer in building a world science and technology powerhouse, and make due major innovative contributions as a national strategic scientific and technological force to building a prosperous, strong, democratic, civilized, harmonious, and beautiful modern socialist country.

With the thinking of "high starting point, large pattern, full chain, and new mechanism," CAS will integrate and consolidate advantageous forces, actively participate in building Beijing and Shanghai into globally influential scientific and technological innovation centers, jointly build comprehensive national science centers in Beijing Huairou, Shanghai Zhangjiang, and Anhui Hefei, actively participate in and support the planning and construction development of Xiong'an New Area in Hebei and the Guangdong-Hong Kong-Macao Greater Bay Area international scientific and technological innovation center, build international first-class scientific and technological innovation highlands, and create sources of major original achievements.

According to the unified deployment of the Party Central Committee and the State Council, CAS will take the lead in planning and promoting national laboratory construction, actively undertake the "Scientific and Technological Innovation 2030—Major Projects," conscientiously implement major scientific and technological tasks such as national major scientific and technological infrastructure construction, CAS strategic pilot science and technology special projects, and defense science and technological innovation, and produce more internationally leading major innovative achievements.

CAS will actively promote the R&D and incubation of key core technologies, the transformation of scientific and technological achievements, and the development of high-tech industries, provide more mid-to-high-end scientific and technological supply for deepening supply-side structural reform and shaping leading development, transform scientific and technological advantages into powerful new drivers for high-quality economic and social development, and provide strategic support for building a modern economic system.

Focusing on the key area directions determined by the national and CAS "13th Five-Year" plans, CAS will deeply implement the "One-Three-Five" plan of institutes, solidly advance institute classification reform, accelerate the construction of world-class research institutions, and continuously improve the capacity for major scientific and technological achievements output.

Focusing on the goal of building a world science and technology powerhouse, CAS will plan forward-looking medium- and long-term scientific and technological development, strengthen the layout of major innovation fields, further seize the commanding heights of international competition, and strive to comprehensively achieve running alongside and leading in major scientific and technological fields at an early date.

CAS will accelerate the pace of “going global” in science and technology, actively participate in the global innovation network and science and technology governance, strengthen “Belt and Road” international science and technological cooperation, represent the country in launching international big science plans, and further enhance China’ s position, influence, and competitiveness in the global innovation landscape.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv –Machine translation. Verify with original.