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Keywords

guiding principle; Pioneer Initiative; innovation and development

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Abstract: This paper reviews the historical background, main contents, policy logic, and reform practice of the six guiding principle adjustments of the Chinese Academy of Sciences (CAS). Particularly, we focus on the logical starting point, main measures, and main results of the first phase of the "Pioneer Initiative" of CAS, and summarize the experience and enlightenment of the development of national strategic scientific and technological forces.
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Chinese Academy of Sciences (CAS) has been established for over 70 years, during which it has adjusted its guiding principles for six times successively. Systematically sorting out the historical background and policy logic of the six guiding principle adjustments and their corresponding reform practices and preliminarily summarizing the main measures and progress of reform and development since the implementation of the "Pioneer Initiative" have certain enlightenment in better implementing the initiative, deepening reform of the science and technology system of China, and promoting the construction of an innovative country and a world power of science and technology.

1 Historical background and policy logic of the CAS's guiding principle adjustments and corresponding reform practices

Determination of the first guiding principle and the reform and development under its guidance at the beginning of CAS establishment. On November 1, 1949, CAS was established. In June 1950, in response to the urgent development and construction needs of many aspects in China, including science and technology field, the basic principle of CAS was determined in line with the documents of the Government Administration Council of China: "in accordance with the cultural and educational policies stipulated in the Common Program of Chinese People's Political Consultative Conference, the past scientific research institutions should be reformed in order to cultivate scientific talents, so that scientific research can truly serve the construction of industry, agriculture, health care, and national defense of our country." This was the first time for CAS to make clear the guiding principle. Since then, under the leadership of the Science Planning Committee of the State Council, the CAS cooperated with many leaders and experts in various ministries and commissions in various fields and formulated the Long-term Plan for Science and Technology Development 1956–1967 (hereinafter referred to as "Twelve-year Plan for Science and Technology"). Among the 57 tasks identified in the plan, the tasks with the CAS as the "main responsible unit," "joint responsible unit," and "main cooperating unit" accounted for 87.7% of all tasks, which fully reflected the role of the "engine" of scientific and technological innovation and the national strategic scientific and technological force [1]. With the implementation of the Twelve-year Plan for Science and Technology and the guiding principle, the scientific research institutions directly affiliated to the CAS developed rapidly, and the scientific research team grew stronger. Before 1966, the CAS had developed into a comprehensive scientific research institution with 106 research institutes and more than 60,000 employees. The accumulation and growth of the scientific research capabilities of the CAS made it play an important role in supporting the implementation of major national strategies of China, such as the "two bombs and one satellite," and promoting the production of major original achievements, such as synthesis of bovine insulin.

Controversy caused by the second and third guiding principles and their determination. After 1976, the work focus of the Communist Party of China (CPC) and the country shifted to economic construction. How science and technology serve economic construction is a major issue faced by the CAS. At the National Science Conference held in March 1978, Deng Xiaoping made the important judgment that "science and technology are productive forces," which provided theoretical guidance for the development of science and technology.

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The conference deliberated and approved the *National Science and Technology Development Plan Outline for 1978–1985 (Draft)*, which clearly stated that "as a comprehensive center of natural science research of China, CAS had the main tasks to research and develop new theories and new technologies of natural sciences, to cooperate with relevant departments to solve comprehensive and major scientific and technological problems in the construction of the national economy. Foundation and improvement should be both focused on." According to this definition, at the Enlarged Meeting of CAS Affairs held in 1979, the guiding principles were summarized as: "focusing on both foundation and improvement, and serving the national economy and national defense construction" ("two focuses, two services" for short). This was the second time that the CAS made clear the guiding principle, which however was quickly adjusted [2]. At the end of 1983, the Secretariat of the Central Committee of the CPC issued instructions on the principles and tasks of the CAS, requiring that "CAS should vigorously strengthen applied research, actively and selectively participate in exploitation and development work, and continue to attach importance to fundamental research." In January 1984, in accordance with the guideline of the central government, the CAS officially published the new guiding principle, namely, "vigorously strengthening applied research, actively and selectively participating in development work, and continuing to attach importance to fundamental research," which became the third guiding principle determined by the CAS. During this period, the discussion and adjustment regarding the guiding principle of CAS were essentially to deal with the following relationships: between the positioning of the CAS and the national development strategy; among different types of scientific research activities, such as fundamental research, applied research, and development experiments; between the government and the market and between the economic construction and scientific and technological innovation; between the development of science and technology themselves and their development driven by economy and society. These are also the major issues that have always affected the reform and development of the CAS.

Formation of the fourth guiding principle and the reform and development under its guidance. In 1985, for the sake of promoting economic construction more effectively, the scientific and technological system reform of China was carried out in an all-round way around the relationship of science and technology with economy. According to the requirements of the new situation and the development needs of the CAS, in early 1987, the CAS proposed the guiding principle of "mobilizing and organizing the main forces to the main battlefield of national economic construction, while maintaining a capable force to engage in the fundamental research and high-tech follow-up" in the report of the reform plan to the central government, which was approved by the central government. In 1991, it was revised to "mobilizing and organizing the main forces to the main battlefield of serving national economic and social development, while maintaining a capable force to engage in the fundamental research and high-tech innovation." This was the fourth time that the CAS established the guiding principle. In 1988, on the basis of the above principles, the CAS put forward the idea of "One Academy, Two Systems." To be specific, the CAS should build a group of international-level research institutes (new scientific research system) and create a group of export-oriented high-tech enterprises (new technological development system) [3], so as to adopt different management models and evaluation criteria for the two different work types, i.e., scientific research and technological development. Under the guidance of this principle, a large number of research institutes and scientific researchers of the CAS set up enterprises in Zhongguancun. This set off a wave of entrepreneurship by Chinese scientific researchers and promoted the development of a large number of high-tech enterprises, such as Lenovo, Stone, and ScienceSea, thus making a great contribution to the national economy and verifying the reform effect of the CAS. However, the overall research quality and the ability to solve fundamental research problems of the CAS were impaired to a certain extent due to the demission of a large number of scientific researchers.

Proposal of the fifth guiding principle and the reform and development under its guidance. At the turn of the century, the knowledge-based economy is surging and poses new requirements and challenges to the CAS. At the end of 1997, the CAS submitted a research report entitled *Welcome the Era of Knowledge-based Economy and Build the National Innovation System* to the central government [4]. In 1998, the Central Committee of the Communist Party of China and the State Council made a great decision to build a national innovation system and decided that the CAS should launch a pilot knowledge innovation project. In January 2002, in accordance with the spirits of the important instructions and inscriptions of the central leadership, the CAS summarized the practices of the pilot knowledge innovation project and proposed new guiding principles, namely, "facing the national strategic needs, targeting the scientific frontiers in the world, strengthening original scientific innovations, promoting key technologies innovation and integration, climbing the world technology peaks, and continuously making great fundamental, strategic, and forward-looking innovation contributions to the economic construction, national security, and sustainable social development of China" ("Three Natures and One Climbing"). This was also the fifth time that the CAS established the guiding principle. During the period of the knowledge innovation project, the basic conditions for scientific research were improved significantly. The CAS made efforts to firmly grasp the strategic opportunities, optimize the scientific research layout, create new management models, accelerate the transformation and application of scientific and technological achievements, cultivate innovative talents, and foster an innovative culture, thus continuously achieving major innovation results and

strengthening the independent innovation capabilities. The CAS had made significant progress in high-tech research (e.g., manned aerospace engineering and Loongson series chips), fundamental research (e.g., laser physics and nanotechnology), and strategic tasks (e.g., Qinghai-Tibet Railway and new energy exploration) and made important contributions to the economic development, social progress, and national security of China. However, at the same time of rapid development, repeated layout and blind expansion also began to emerge.

Determination of the sixth guiding principle. Since the 18th National Congress of the Communist Party of China, the Central Committee of the Party with General Secretary Xi Jinping as the core has attached great importance to scientific and technological innovation, regarded innovation as the first driving force for development, and deeply implemented the innovation-driven development strategy. On July 17, 2013, General Secretary Xi Jinping inspected the CAS and delivered an important speech which required the CAS to "take the lead in realizing the leapfrog development of science and technology, setting up a highland of national innovative talents, constructing a national high-level science and technology think-tank, and building world first-class scientific research institution" ("four leads"). On August 8, 2014, General Secretary Xi Jinping gave important instructions to the "Pioneer Initiative" of the CAS and further required the CAS to "face the world science and technology frontiers, the major national needs, and the main battlefield of the national economy" ("three orientations"). In February 2015, in order to implement the spirits of the important speech and instructions of the General Secretary Xi Jinping, the Party Group of the CAS established the guiding principle for the new era on the basis of the contents of "three orientations" and "four leads" and led the comprehensive reform of the CAS and the deep implementation of the "Pioneer Initiative."

2 Logical starting point, main measures, and main results of the first phase of the "Pioneer Initiative" of CAS

In order to implement the requirements of "three orientations" and "four leads" proposed by General Secretary Xi Jinping, relying on in-depth research and brainstorming, the Party Group of the CAS made great efforts to solve the problems of low-level repetition, homogenization-induced competition, and fragmented expansion. On the basis of development goals of making major innovation achievements, creating forward-looking innovative ideas, and cultivating outstanding innovative talents, the CAS researched and formulated the "Pioneer Initiative" and proposed 25 reform and development measures in 5 areas, including promoting the classification reform of the institutes, adjusting and optimizing the scientific research layout, deepening the reform of the talents and personnel systems, building a high-level scientific and technological think-tank, and comprehensively expanding the opening up and cooperation. On July 7, 2014, the Seventh Meeting of the National Leading Group for the Scientific and Technological System Reform and the Innovation System Construction deliberated and approved the "Pioneer Initiative" and the Outline for Comprehensively Deepening Reform of the CAS. Subsequently, the Party Group of the CAS formulated the Plan for the Organization and Implementation of the "Pioneer Initiative" of CAS. The "Pioneer Initiative" became the action plan outlining the reform and development of the CAS.

2.1 Logical starting point and preliminary preparations for the reform of the CAS

(1) Ideological preparation for reform: a great discussion on the positioning of the CAS. On the basis of the new situation of the economic and social development of China and the new work requirements for the CAS, the Party Group of the CAS proposed important propositions about "What the orientation of the CAS is on earth" and "What things the CAS can 'refuse'" to the whole Academy at the Winter Party Group Enlarged Meeting held on December 24, 2012, which were sent to the main leaders of the Academy-affiliated units through the "President Mailbox" as a "homework." This triggered a wide range of discussion across the Academy and made ideological preparations for the timely adjustment of the CAS's guiding principles in the new era and for the whole Academy to start a comprehensive reform and to organize and implement the "Pioneer Initiative."

(2) Theoretical guidance of reform: a dialectical understanding of science, technology, and engineering. At present, the science and technology development in the world, on the one hand, is more and more presenting a trend of integrative development and fuzzy boundary between science and technology and between fundamental research and applications and is showing the characteristics of the scientific research forces in various fields collaboratively tackling major problems. On the other hand, we still need to seriously research the characteristics and laws of different types of scientific research activities, such as scientific discovery, technological invention, and project implementation and should recognize and manage by categories. The Party Group of the CAS has carefully studied and analyzed the dialectical relationship among science, technology, and engineering and published a theoretical article entitled What Supports the Innovation-driven Development Strategy?—Starting with the Concepts of Science, Technology, and Engineering in *Guangming Daily* on May 15, 2014 [5]. Later, this article was reprinted by *Xinhua Digest*, which produced a positive impact both inside and outside the Academy and became the theoretical basis for the CAS to organize the "Pioneer Initiative," especially to carry out the classification reform of research institutes and implement Strategic Priority Research Programme (hereinafter referred to as the "Priority Programme").

(3) Framework basis of reform: establishment of Innovation

2020, a leap development framework of CAS. On March 31, 2010, the 105th Executive Meeting of the State Council of China deliberated and approved in principle the Report on the Leap Development of the Knowledge Innovation Project 2020 of the Chinese Academy of Sciences ("Innovation 2020" for short). At the Summer Party Group Enlarged Meeting 2012 of the CAS, the Party Group stated the connotation of the "Innovation 2020" leap development framework and put forward the contents of the development purposes (creating new technologies, serving the country, benefiting the people), strategic positioning (national team, engine, pioneer, think-tank, super university), strategic missions (results, talents, ideology), development strategy (democratic management, open innovation, and talent-based development strategy), development plan ("One-Three-Five" Strategic Planning), development framework ("3-in-1" portfolio of research institutes, academic divisions, and educational institutions, CAS), development measures ("3H Project" ①), and development evaluation (orientated by major achievement output), which have become the framework basis for the CAS to formulate and implement the "Pioneer Initiative."

(4) Organizational guarantee for reform: rapid implementation of scientific research management reform of CAS headquarters. In order to effectively lead the in-depth reform of the whole Academy, in early 2013, the CAS carried out the scientific research management reform of the CAS headquarters and improved the scientific research management and organization system and operation mechanism in accordance with the requirements of being "scientific, collaborative, standardized, and efficient." Two sequences of scientific research business management and comprehensive functional management were set up. The scientific research business management was set according to the nature and functional characteristics of scientific and technological innovation activities, and different management methods and evaluation methods were adopted. The scientific research business management formed a matrix management model according to the scientific and technological innovation value chain and subject areas. The scientific research management reform of the CAS headquarters has improved its work strategy, coordination, and execution and provided organizational guarantee for comprehensively deepening the reform of the CAS and deeply implementing the "Pioneer Initiative."

2.2 Main measures and effects of the "Pioneer Initiative" reform

2.2.1 Classification reform of research institutes: exploring the establishment of four types of scientific research institutions based on the characteristics and laws of scientific and technological innovation activities of different natures

The classification reform of the research institutes is the focus and breakthrough point of the "Pioneer Initiative." According to the characteristics and laws of scientific and technological innovation activities of different natures, the CAS has systematically adjusted, simplified, and optimized existing scientific research institutions, and made efforts to build innovation research institutes for major national needs, found excellent innovation centers targeting basic scientific frontiers, set up research centers on big science on the basis of major national scientific and technological infrastructures, and establish characteristic research institutes on the basis of characteristic and preponderant disciplines. The systems and mechanisms of classification positioning, classification management, and classification evaluation were established for the "four types of institutions." As of August 2019, 23 innovation research institutes had been built and 8 of them had been officially put into operation; 23 excellent innovation centers had been built and 13 of them had been in formal operation; 5 research centers on big science had been built and 3 of them had been officially put into operation; 17 characteristic research institutes had been built and 14 of them had begun to officially operate. Among the above 68 "four types of institutions," 3 innovation research institutes (microsatellites, aerospace information, and precision measurement), 3 excellent innovation centers (brain science and intelligent technology, molecular plant sciences, and molecular cell sciences), and the nutrition and health institute had been approved by the State Commission Office of Public Sectors Reform, thus making progress in the legal entity reform of the "four types of institutions."

The classification reform of the research institutes effectively integrates high-quality innovation resources inside and outside the CAS, promotes cross-institution, cross-discipline, and cross-field collaborative innovation, strengthens the overall advantages and strategic layout in major innovation fields, cultivates new innovation growth points, and lays the foundation for the construction of national laboratories and comprehensive national science centers.

2.2.2 Adjustment of scientific research layout: implementing the "One-Three-Five" Strategic Planning and Priority Programme and striving to break the inherent patterns of low-level repetition, homogenization-induced competition, and fragmented development

Organizing the implementation of the "One-Three-Five" Strategic Planning and Priority Programme are key measures of the "Pioneer Initiative." The "One-Three-Five" Strategic Planning means that institutes clarify "one orientation, three major breakthroughs, and five key cultivation directions" on the basis of analyzing their own advantages and core competitive competences. In the Development Plan Outline of CAS during the "13th Five-year Plan" Period formulated in

① "3H Project" is an important task for the Chinese Academy of Sciences to build a relatively perfect "Big Logistics" support system that mainly focuses on housing, home, and health.

2016, 104 research institutions throughout the Academy summarized and proposed 60 major breakthroughs that are expected to achieve leapfrog development and 80 key cultivation directions for shaping new advantages in future development. Focusing on the combination of national strategic needs, scientific and technological development frontiers, and basic advantages of the Academy, the Priority Programme organizes cross-institution, cross-discipline, cross-field, and even cross-border scientific research forces to jointly tackle key problems and is committed to achieving major innovation results. As of the end of 2019, 23 class A priority programs aiming to resolve forward-looking strategic technological problems have been implemented, and 32 class B priority programs aiming to face the basic frontiers and achieve leading original results have been implemented, and for the class C priority programs aiming to tackle the key core technologies and other "bottleneck" problems, 3 have been implemented and 5 have been deployed.

This reform measure makes the Academy and the institutes further clarify the orientations, condense the goals, focus on the key points, and integrate the resources. The scientific and technological layout of the CAS has been adjusted and optimized.

2.2.3 Reform of resource allocation methods: exploring a more scientific and effective scientific research evaluation system and forming a preferential support model oriented by the output of major achievements

Exploring the establishment of a resource allocation and scientific research evaluation system oriented by the output of major achievements is an important measure of the "Pioneer Initiative." In accordance with the principles of "guaranteeing key projects, supporting excellent projects, clarifying rights and responsibilities, and strengthening performance," the CAS establishes a resource allocation system oriented by realizing the output of major original results, major strategic technologies and products, and major demonstration transformation projects ("three majors" for short). It is necessary to give full play to the overall planning role of Academy-level funds, which are mainly used for the construction of projects, talents, and conditions that have an overall effect and are expected to form major outputs and major social and economic benefits. At the same time, centered on the classification reform of research institutes and implementation of the Priority Programme, the CAS formed an allocation model of "supporting key projects + supporting special projects" according to the principles of "accurate positioning, reasonable scale, clear standards, and comprehensive budget."

Through this series of reforms, "guaranteeing major output, major reforms, and key talents" are highlighted, which improve the fund utilization efficiency and strengthen the ability to guarantee major tasks and major projects.

2.2.4 Construction of regional innovation highlands: building a systematic and intensive spatial layout for mid- to long-term development and creating regional innovation clusters with various advantages

Since the 18th National Congress of the Communist Party of China, the Central Committee of the Communist Party of China and the State Council have made a series of major strategic deployments on regional innovation and development. The CAS seizes the opportunities, takes advantage of science, technology, and talents, and integrates the relevant research forces of the whole Academy to actively participate in the construction of regional innovation highlands and continuously expand the "Pioneer Initiative." It strengthens intellectual property management, builds the science and technology service network (STS), and promotes the transformation of knowledge and technological achievements. Various tasks are implemented in an all-round way for the construction of comprehensive national science centers in Huairou of Beijing, Zhangjiang High-tech Park of Shanghai, and Hefei of Anhui. Besides, CAS also conducted the followings for the construction of regional innovation highlands: signing a framework agreement with Hebei Province for co-building the Xiong'an New Area Innovation Research Institute, actively planning and deploying the construction tasks of Science and Technology Innovation Center in the Guangdong-Hong Kong-Macao Greater Bay Area, starting the construction of Pearl Science Park of CAS in Nansha, Guangzhou, completing the registration of the Hong Kong Institute of Science & Innovation, CAS in Hong Kong, co-building the rare earth research institute with Jiangxi Province, and co-building the science and education parks in Nanjing, Qingdao, Chengdu, Wuhan, Chongqing, Xi'an, Taiyuan, and some other places.

The adjustment of the regional distribution of scientific research forces has made scientific research institutions affiliated to the CAS more intensive in space and more convenient in management, thus laying the foundation and creating the conditions for the all-round support for the construction of national and regional innovation highlands.

2.2.5 Reform of the talent cultivation mechanism: implementing the combination of education and research training to continuously improve the cultivation ability and quality of innovative and entrepreneurial talents

The CAS deeply implements talent cultivation and introduction system projects to further improve the international competitiveness of attracting and gathering outstanding talents; it actively promotes the reform of the CAS membership election and management systems to maintain the academic and honorary natures of the CAS member title; it improves the open, flexible, competitive, and cooperative employment mechanism to enhance the overall level and ability of the team; it optimizes the innovation ecosystem, deepens the

implementation of the "3H Project," and creates a good environment for the researchers to keep their minds on the research and show their abilities. In particular, the CAS gives full play to the advantages of its "3-in-1" portfolio, deepens the implementation of combining education and research training, and insists on cultivating high-level innovative and entrepreneurial talents in high-level scientific research practices. In July 2012, the Graduate School of the Chinese Academy of Sciences was renamed the University of Chinese Academy of Sciences (UCAS). In 2014, UCAS began to enroll undergraduate students. The University of Science and Technology of China (USTC) and the UCAS have taken important steps to build world-class universities. The co-building of Shanghai Tech University with Shanghai, the co-building of CAS Shenzhen University of Technology with Shenzhen, and the commencement of construction of UCAS Chongqing College, Chengdu College, Xi'an College, Nanjing College, and Taiyuan Energy College form a higher education development pattern matching with the national and regional development and innovation highland construction. Since the comprehensive implementation of the "Pioneer Initiative" in 2014, 2 scientists of the CAS have won the Highest Science and Technology Awards; 70 scientists have been elected as members of the CAS and the Chinese Academy of Engineering; 388 people have been funded by the National Science Fund for Distinguished Young Scholars of China, and 557 people have been funded by China's Excellent Young Scientists Fund. Since 2014, the universities affiliated to the CAS have accumulatively awarded 11,157 bachelor degrees, 44,826 master degrees, and 36,672 doctoral degrees.

High-level scientific and technological talents are the key to improving scientific and technological innovation capacities. In particular, in the face of the new situation of Sino-US economic and trade frictions, we must adhere to the combination of cultivation and introduction and pay more attention to self-cultivation. The model of CAS deepening the implementation of combining education and research training and cultivating high-level innovative and entrepreneurial talents is of demonstration significance.

2.2.6 Construction of science and technology think-tanks: strengthening the orientation of output of major forward-looking innovation thoughts and focusing on exploring the construction of national high-end science and technology think-tanks

Building high-end science and technology think-tanks is an important task and measure for the implementation of the "Pioneer Initiative." The CAS Science and Technology Think-Tank Council is established to comprehensively lead, plan, and coordinate the research, resources, team and platform construction of the whole Academy's science and technology think-tanks, which gradually forms a think-tank construction structure and system mechanism with "small core and large network." The CAS gives full play to the leading role of the CAS Academic Divisions as the highest advisory body for science and technology of China, integrates and establishes the Institutes of Science and Development, CAS as a legal entity, builds a research system of science and technology think-tanks led by the CAS Academic Divisions, supported by the Institutes of Science and Development, CAS, and with the institutes affiliated to the CAS giving play to their specialized skills, and forms a hierarchical, systematic, open, and cooperative research layout with the organic integration between the CAS Academic Divisions and departments. In the comprehensive evaluation of the pilot work of the national high-end think-tanks, the CAS ranks top.

By strengthening the construction of high-end science and technology think-tanks, the CAS not only provides effective service support for China to formulate and improve science and technology policies and make scientific decisions but also promotes itself to timely grasp the development trend of science and technology, improve various reform measures, and achieve sound and rapid development.

2.2.7 Deepening openness and cooperation: facing the world science and technology frontiers and the major global common issues, focusing on the "Belt and Road" and other major national initiatives, and comprehensively promoting international development strategies

Open cooperation and collaborative innovation are important measures to be promoted by the "Pioneer Initiative." In recent years, the CAS has accelerated its integration into the global innovation network, continuously strengthened cooperation with technologically developed countries and regions (e.g., the United States, Europe, Japan, and Russia), and actively expanded scientific and technological exchanges and cooperation with developing countries. It actively participates in the construction of international science and technology organizations and plays a leading role in international science and technology organizations, such as the Third World Academy of Sciences (TWAS) and the International Council of Scientific Unions (ICSU). It takes the lead in establishing 10 overseas science and education cooperation centers and achieves the breakthrough of zero in the number of overseas scientific research institutions of China. It takes the lead in establishing the Alliance of International Science Organization in the Belt and Road Region (ANSO), which becomes the first comprehensive international academic organization initiated by China. In addition, CAS actively participates in the implementation and initiation of international big science programme.

The deepening of international scientific and technological cooperation has reduced the gap between the CAS and international high-level scientific research institutions to a certain extent and increased the influence of China in the global innovation pattern.

2020 is the closing year of the first phase of the CAS's

"Pioneer Initiative." Through comprehensively deepening the reforms, the CAS has output a number of major innovation results and has made positive contributions in quickly responding to major national innovation needs and systematically coping with major scientific and technological risks and challenges. For example: ① In terms of major innovation results output. Through implementing the Priority Programme and undertaking a series of major national scientific and technological tasks, CAS gradually enters the international advanced or leading ranks in the frontier fields of iron-based high-temperature superconductivity, quantum communication, neutrino oscillation, advanced nuclear energy, stem cells, and gene editing. Besides, CAS achieves breakthroughs in a number of key core technologies in deep space, deep sea, cyberspace security, and artificial intelligence (Figure 1a), supercomputing (Figure 1b), and other major strategic fields. A number of major scientific and technological achievements and transformation demonstration projects have taken root in the fields of new medicine development, clean and efficient utilization of coal, agricultural science and technology, resource ecological environment, disaster prevention and relief. CAS completes a Five-hundred-meter Aperture Spherical Radio Telescope (FAST), China Spallation Neutron Source (CSNS), Steady High Magnetic Field Facility (SHMFF), and a number of other big science facilities (Figure 2), which lay the material and technological foundation for further enhancing the scientific and technological innovation capabilities of China. The successful launch of China's Dark Matter Particle Explorer "Wukong," China's first Hard X-ray Modulation Telescope "Huiyan," and the world's first Quantum Experiments at Space Scale with "Mozi" have caused the widespread social impact. CAS has also played an important front army role in scientific and technological innovation for national defense. ② In terms of coping with the key core "bottleneck" technologies. After the outbreak of Sino-US economic and trade frictions in 2018, the CAS seriously summarized the experience and practices of organizing and implementing class A and class B Priority Programme. On the basis of the existing accumulated researches, CAS integrated the relevant research forces, and quickly organized and deployed the class C Priority Programme aiming to break through the "bottleneck" technologies. Although the first three class C programs have been implemented for just over a year, we have made positive progress in the development of domestic safe and controllable advanced computing systems. ③ In terms of scientific research on the prevention and control of the COVID-19. Relying on the "four types of institutions" (including the Stem Cell and Regenerative Medicine Institute, the Institute of Drug Discovery and Development, the Center for Biosafety Mega-science, and the Center for Excellence in Nanoscience, CAS) and the multidisciplinary and institutionalization advantages of the related research institutes, CAS has organized 400 teams and nearly 3,000 scientific researchers throughout the Academy to participate in the scientific research on epidemic prevention and control, produced a number of innovation results in the research and development of rapid detection technology, drug, vaccine, and antibody, as well as in the tracing the source of the virus, and also accumulated valuable experience for organizing to respond to major public health events.

3 Enlightenment from guiding principle adjustments and the corresponding reform practices of the CAS

(1) Abiding by the orientation of the national strategic scientific and technological forces, always finding the correct coordinates in the national overall situation and national strategy, and timely adjusting the work policy and main tasks. As a national strategic scientific and technological force, the CAS should always take the state will as its mission and take the national need as its development direction. In different economic and social development periods after the founding of the People's Republic of China, the CAS has reviewed the situation, kept pace with the times, timely adjusted the guiding principle, and made great contributions to serving and supporting the national major needs. In the initial stage of its establishment, the CAS rapidly established institutes, built teams, created disciplines, and cultivated talents to implement the "Twelve-Year Plan for Science and Technology," form a relatively complete discipline system, and lay an innovation foundation for the long-term development of science and technology, strengthening of national defense capabilities, and economic and social progress of China. Since the reform and opening up, the CAS implemented the policies of "two focuses, two services" and "One Academy, Two Systems." At the same time of stabilizing the fundamental research forces, in the main battlefield of the national economy, the CAS played a positive role in promoting economic construction through increasing the application of scientific and technological achievements and developing high-tech industries. During the period of comprehensively deepening the reform, the CAS implemented the policies of "three natures and one climbing," put the "three orientations" and "four leads" policies into practice, and concentrated forces to plan for and make efforts to the key core technology research and other national major needs, research in world scientific and technological frontier fields, and high-quality economic development, comprehensively enhanced the capability of independent innovation, and provided strong support for the implementation of the innovation-driven development strategy and the building of a world scientific and technological power.

(2) Strengthening the top-level design, overall planning, and implementation of reforms and paying attention to the systematicness and synergy of reform. The guiding principle adjustments of the CAS and the reform under the principles

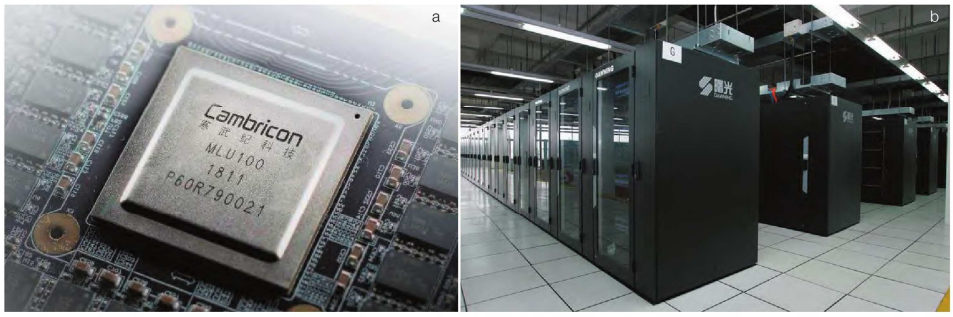

Figure 1 Artificial intelligence chip–"Cambrian" (a) and supercomputing-Sugon high-performance computer (b)

Figure 2 Big science facilities developed by CAS: Five-hundred-meter Aperture Spherical Radio Telescope (a), China Spallation Neutron Source (b), Steady High Magnetic Field Facility (c)

are a complex system project that requires extensive publicity and implementation, consensus, top-level design, overall planning, formulation of plans, and fulfillment of responsibilities. For example, all activities occurring during the implementation of the "Pioneer Initiative," from the great discussion on the orientation of CAS to the theoretical understanding of science, technology, and engineering, from the reform of the scientific research management of the CAS headquarters to the reform of "four types of institutions," from the implementation of the "One-Three-Five" Strategic Planning in institutes to integrating the resources of the whole Academy to carry out Priority Programme, not only reflect the classification management of scientific research activities of different natures and follow the scientific research laws to improve management efficiency but also strengthen and give play to the institutional advantages, concentrate on major scientific research tasks to carry out coordinated research, and strive to output major results. During this period, the CAS achieved the results of forming a consensus in theory, formed an atmosphere in public opinion, provided organizational guarantee, and formed "four beams and eight pillars" in the framework, so as to strive to organically link the implementation of Priority Programme with the construction of "four types of institutions." CAS strengthened high-level talent cultivation through implementing the combination of education and research training, implemented international strategies to strengthen open cooperation, established physical strategic consulting institute to strengthen the construction of science and technology think-tanks, and made corresponding institutional arrangements in scientific research evaluation and resource allocation, so that CAS can guide, guarantee, and comprehensively promote the progress of reforms, thus stabilizing the talent team, forming a joint force for reform, and ensuring the reform effect.

(3) On the basis of grasping the scientific and technological development trends and following the laws of scientific and technological innovation, paying attention to serve and meet the major needs of the national economic and social development and ensuring the directions of reform and development. The guiding principle adjustment of the CAS once caused fierce debates inside and outside the Academy and even high concern of the central government. The purpose of the CAS, a national team of science and technology, is to strengthen the orientation of fundamental research and highlight basic, original, forward-looking, and long-term research tasks and layout or to strengthen the orientation of applied research and highlight facing the national central tasks and serving the national strategic needs, which is the key point in the debates. The practices of reform and development of the CAS over the past 70 years fully prove that as a national strategic scientific and technological force, it needs not only to fully reflect the state will and serve the strategic needs of the country but also to follow the laws of scientific and technological development and adapt to the trends and requirements of world scientific and technological development. From participation in "two bombs and one satellite" to the technological research on manned spaceflight, manned deep diving (Figure 3) and abyss scientific expedition, from new industrial production technology of *cis*-polybutadiene to coal-to-olefin technology and industrial application, from participation in artemisinin synthesis to the successful release of Sodium Oligomannate Capsules (GV-971) (Figure 4), from the transformation of the medium- and low-yield fields in Huang-Huai-Hai Region to biological

breeding, and from participation in the world's first synthesis of bovine insulin to the realization of somatic cell clone of monkey for the first time (Figure 5)…, these are all the results of the combined action of national strategic needs and scientific and technological development requirements and the integrated development of basic research and applied research.

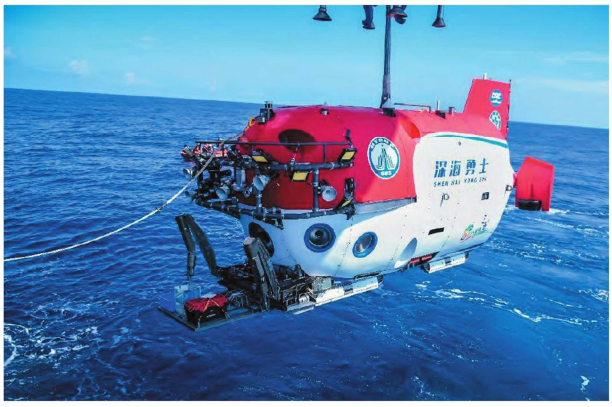

Figure 3 "Deep Sea Warrior" manned submersible

Figure 4 Box and capsule samples of Jiuqiyi (Sodium Oligomannate Capsules)

(4) Scientifically studying and judging the trends, actively seizing the opportunities, proactively making overall plan and arrangement, and promoting the realization of leap development of scientific and technological innovation. At present, the competition for science and technology is becoming fiercer, and in order to win opportunities and achieve development, we must always scientifically study and judge the trends and make arrangement for tackling key problems in advance. For example, as early as in the "Twelve-year Plan for Science and Technology," the basic theoretical issues were included, such as "the research on protein structure, function, and synthesis." Under the guidance of the "Twelve-year Plan for Science and Technology" and the guiding principle at that time, the Shanghai Institute of Biochemistry and Cell Biology (CAS), Shanghai Institute of Organic Chemistry (CAS), and the Department of Chemistry of Peking University cooperated and successfully synthesized bovine insulin in the world for the first time in 1965, making the protein synthesis technology of China reach the world-class level. Quantum technology was once regarded as a field which required huge investment but had only limited development space by developed countries in Europe and the United States. However, with the support of China, the CAS has conducted continuous research in this field for nearly 20 years. Especially in recent years, through organizing and implementing Priority Programme, establishing innovation research institutes and other measures, the CSA strongly supported quantum science and technology research and achieved a series of important results, making China is partially superior to European and American countries in this field.

Figure 5 Cloned monkeys "Zhongzhong" and "Huahua"

(5) Always implementing the "science, democracy, patriotism, dedication" and "true, realistic, collaborative, innovative" spirits throughout the entire reform and development process and striving to build an innovative culture. In order to implement the guiding principle, we should make great efforts to build an innovative culture that reflects the laws of scientific research and the spirit of the era and concentrate on promoting reform and development. From 2000 to 2015, the CAS successively issued five guiding opinions and one 10-year construction outline regarding the construction of innovative culture. During this period, the CAS energetically promoted the traditions of "science, democracy, patriotism, dedication" and the "true, realistic, collaborative, innovative" academic styles, firmly established the science and technology value of "creating new science and technology, serving the country and the people," advocated scientific spirits, established good scientific research ethics and academic atmosphere, and built a vibrant, inclusive, harmonious and orderly, open and interactive innovation ecosystem, providing a strong spiritual power for deep reform and sustainable development. The continuous deepening of the innovation culture construction theory and practice has played a positive

role in the deep implementation of the knowledge innovation project and the "Pioneer Initiative" of the CAS and in achieving solid results.

(6) Giving full play to the advantages of complete disciplines and institutionalization, paying attention to accumulation, strengthening coordination, and striving to take on the heavy burden for coping with the major scientific and technological risks and challenges in economic and social development. Serving the national strategic needs and actively participating in the work against the major scientific and technological risks often require multidisciplinary knowledge and an organized team to form efficient response and group fighting ability. In the history of the reform and development of the CAS, this is not only reflected in the active participation in the implementation of the "two bombs and one satellite" project but also in scientific research on coping with "bottleneck" technologies and the COVID-19 in recent years. During the implementation of the "Pioneer Initiative," both the construction of innovation research institutes and the organization and implementation of the Priority Programme have broken the barriers between different research institutes and different disciplines and gathered the preponderant foundations and forces of relevant research institutions inside and outside the Academy. For example, the Center for Excellence in Quantum Information and Quantum Physics, CAS (Figure 6), on the basis of the Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, CAS, further integrated the preponderant research forces in the field of quantum information and quantum technology and gathered preponderant resources from more than 20 universities, scientific research institutes, and related enterprises throughout the country to make whole-chain arrangements for the "bottleneck" risks of quantum technology and spare no effort to solve a series of frontier scientific issues (e.g., quantum communication, quantum computing, quantum precision measurement, quantum materials and devices). It breaks a series of key technologies and core devices and has achieved remarkable results.

Figure 6 The Center for Excellence in Quantum Information and Quantum Physics, CAS under construction

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