Bulletin of Chinese Academy of Sciences 院刊

Volume 37 | Issue 5 Article 9

5-20-2022

Orientation and Role of National Scientific Research Institutions in National Strategic Scientific and Technological Strength

Chunliang FAN
Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China, fcl@casisd.cn

See next page for additional authors

Recommended Citation

FAN, Chunliang and LI, Zhe (2022) "Orientation and Role of National Scientific Research Institutions in National Strategic Scientific and Technological Strength," *Bulletin of Chin[ese Academy] of Sciences (Chinese Version)*: Vol. 37 : Iss. 5 , Article 9.
DOI: https://doi.org/10.16418/j.issn.1000-3045.20220411002
Available at: https://bulletinofcas.researchcommons.org/journal/vol37/iss5/9

This World Science and Technology Power Construction - Last Ten Years Review and Future Trend of Science and Technology of China - Policy & Management Research is brought to you for free and open access by Bulletin of Chinese Academy of Sciences (Chinese Version). It has been accepted for inclusion in Bulletin of Chinese Academy of Sciences (Chinese Version) by an authorized editor of Bulletin of Chinese Academy of Sciences (Chinese Version). For more information, please contact lcyang@cashq.ac.cn, yjwen@cashq.ac.cn.

Orientation and Role of National Scientific Research Institutions in National Strategic Scientific and Technological Strength

Abstract

An important task of enhancing strategic scientific and technological strength is to strengthen national scientific research institutions. From the history of science and the international development, this study discusses the development of the national research institutions and their characteristics as a national strategic strength of science and technology, and discusses the role of Chinese national research institutions in national development, summarizes the achievements and successful experience of the national research institutions for facing the needs of the country, facing the frontier of science and technology, facing the main economic battlefield, and facing the life and health of the people during past ten years. Based on these discussions, policy suggestions are provided for the future development of national scientific research institutions.

Keywords

national strategic scientific and technological strength; national research institution; Chinese Academy of Sciences; China's space industry; the U.S. National Laboratory

Authors

Chunliang FAN and Zhe LI

This world science and technology power construction - last ten years review and future trend of science and technology of china - policy & management research is available in Bulletin of Chinese Academy of Sciences (Chinese Version): https://bulletinofcas.researchcommons.org/journal/vol37/iss5/9

Citation: FAN Chunliang, LI Zhe. Orientation and Role of National Scientific Research Institutions in National Strategic Scientific and Technological Strength [J]. Bulletin of Chinese Academy of Sciences, 2022 (5).

Orientation and Role of National Scientific Research Institutions in National Strategic Scientific and Technological Strength

FAN Chunliang[1], LI Zhe[2]

1. Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China;
2. Chinese Academy of Science and Technology for Development, Beijing 100038, China

Abstract: An important task of enhancing strategic scientific and technological strength is to strengthen national research institutions. From the history of science and the international development, this study discusses the development of the national research institutions and their characteristics as a national strategic strength of science and technology, and discusses the role of Chinese national research institutions in national development, summarizes the achievements and successful experience of the national research institutions for facing the needs of the country, facing the frontier of science and technology, facing the main economic battlefield, and facing the life and health of the people during past ten years. Based on these discussions, policy suggestions are provided for the future development of national research institutions. **DOI:** 10.16418/j.issn.1000-3045.20220411002-en

Keywords: national strategic scientific and technological strength; national research institutions; Chinese Academy of Sciences; China's space industry; the US National Laboratory

The Fifth Plenary Session of the 19th Communist Party of China (CPC) Central Committee and the 14th Five-Year Plan place the enhancement of the national strategic scientific and technological (sci-tech) strength in an important position. Enhancing the national strategic sci-tech strength is the essential way to accelerate the realization of self-reliance and self-improvement in science and technology and promote the construction of a leading power in science and technology. In addition, it is also an important support for safeguarding national security and improving the comprehensive national strength and international competitiveness of China.

As a vital part of national strategic sci-tech strength, national research institutions are research organizations established in important fields such as economic construction, social development, and national defense to serve national goals and interests. An important task of enhancing national strategic sci-tech strength is to strengthen national research institutions guided by national strategic needs, thereby giving full play to the backbone and leading role of national research institutions.

From the history of science and technology development and international comparison, this paper studied the formation and development of national research institutions and their position and role in national strategic sci-tech strength, especially its role since the founding of the People's Republic of China. This paper summarized the achievements and successful experience of national research institutions for meeting the national strategic needs, and put forward ideas and suggestions for the development of national research institutions in the new era.

1 National research institutions as national strategic sci-tech strength

From the history of science and technology development, national research institutions are the organizations established according to national needs and goals. After World War II, as a national strategic sci-tech strength, national research institutions have developed greatly and played a decisive role in key fields such as national security, international competition, and economic and social development.

1.1 National research institutions are the research organizations established for national interests and goals

From the first scientific revolution in the 16th century to the current days, scientific research has formed three main organizational forms: universities, enterprise R&D institutions, and national research institutions. The Royal Society, founded in 1660, was the earliest scientific organization, which stipulated the rules of scientific activities and founded academic journals. At that time, most members were amateur scientists. The establishment of the French Academy of Sciences in 1666 is more fundamental to the modern scientific organizations. The French Academy of Sciences is the

Received: 2022-05-08
Corresponding author: FAN Chunliang, E-mail: fcl@casisd.cn

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

earliest national research institution in the world. Funded by the government, its academicians were composed of the best experts in various scientific fields. Later, Russia and Germany established their research organizations according to this model. Since the 19th century, with the establishment and development of new research-oriented universities such as the Humboldt University of Berlin, science has matured in the universities, forming research organizations in which teachers led students to engage in free exploration and research. This model was then carried forward in the US and influenced the world. From the second half of the 19th century to the early 20th century, with the development of science-based industries (chemical and electrical industries were the typical ones), enterprises began to set up R&D institutions to engage in the R&D of new products and processes, so as to improve their market competitiveness.

From the second half of the 19th century to the early 20th century, national research institutions have developed rapidly in western countries. A number of research institutions directly invested and managed by the state came into being, with the purpose of serving national interests and goals. These research institutions were established in public fields such as agriculture, geology, and health. Germany's national research institutions were mainly established in the early 20th century. The central government and federal states funded the establishment of 40–50 professional research institutes in application fields such as weather, atmosphere, geography, geology, health, agriculture, fishery, and forestry [1]. After the Civil War (1861–1865), the US established national research institutions. With the process of industrialization in the US, the federal government established a number of research institutions in agriculture, forestry, fishery, meteorology, geology, and other public fields. The US Geological Survey (1879) and the agricultural experimental stations distributed in various states were first established. Subsequently, a number of federal sci-tech institutions and affiliated research institutions were established, including the National Bureau of Standards (1901), the Bureau of Statistics (1902), the Bureau of Mines (1910), the Public Health Service (1912), and the National Aviation Advisory Committee (1915). In 1930, the National Institutes of Health (NIH) was established [2]. After World War I, major countries began to establish military research institutions, such as the United States Naval Research Laboratory.

Before World War II, from a worldwide perspective, three main organizational forms of modern science (universities, enterprise R&D institutions, and national research institutions) have been formed. Universities are mainly engaged in the free exploratory research and the cultivation of talents; enterprise R&D institutions are dominated by the business objectives, mainly engaged in the R&D of new technologies and products, as well as the improvement of products and processes; national research institutions serve national goals and interests, and solve important sci-tech problems in national and social development.

1.2 National research institutions are the main organizational form of national strategic sci-tech strength

The national strategic sci-tech strength came into being during World War II. During World War II, scientific applications and technological inventions produced in a series of wars, such as atomic bomb, radar, and penicillin, have changed the process of the war and showed the decisive role of science and technology. During the war, the main groups and organizations of scientists and engineers engaged in exploration, R&D, and application in the sci-tech fields that influenced and determined the outcome of the war became the the national strategic sci-tech strength [3]. After World War II, especially after the beginning of the Cold War, based on the successful experience of military science and technology during World War II, many countries established large military and civilian research institutions in the fields of national defense, atomic energy, space, and agriculture to build national strategic sci-tech strength. Taking the US as an example, the US has established a national laboratory system based on the Los Alamos National Laboratory and Oak Ridge National Laboratory established by the Manhattan Project, as well as the original laboratories distributed in Berkeley and Chicago. Based on large scientific installations, these laboratories are engaged in a wide range of multidisciplinary research, including physics, chemistry, engineering, biology, and medicine, which not only undertake the research of military technologies such as nuclear weapons, but also extend to the energy system, and promote the development of the frontier of physics and biomedicine. In 1957, after the Soviet Union's first artificial satellite was launched, the Jet Propulsion Laboratory of California Institute of Technology cooperated with the US military in the R&D of satellite launch, and successfully sent the Explorer-1, the first man-made satellite of the US, into space in January 1958 [4]. After that, the National Aeronautics and Space Administration (NASA) was established, the Jet Propulsion Laboratory was used as the federal laboratory, and a number of R&D centers were established, which laid the organizational foundation for the US to finally win the space competition with the Soviet Union. At the same time, the US NIH, the Department of Agriculture, and the Environmental Protection Agency strengthened their support for research institutions in their respective fields. In this way, the United States has deployed a number of strategic sci-tech strength in important national strategic fields (defense, space, energy, health, environment, agriculture, etc.), which has strongly supported the international competition and national development of the US.

As a national strategic sci-tech strength, the role of national research institutions is prominently reflected in the long-term and continuous research on major sci-tech problems in the national strategic fields and mutual cooperation. For example, the wing performance of all aircrafts designed in the US after World War II has been greatly improved, which is own to the long-term research carried out by the National Aviation Advisory Committee (the predecessor of NASA) and the research results of computational fluid dynamics at the National Laboratory of the US [4].

1.3 Characteristics of national research institutions as national strategic sci-tech strength

(1) National research institutions have different organizational forms in different countries. The US national research institutions include various forms, such as government-owned/government-operated research institutions ①, government-owned/contractor-operated research institutions ②, and government-funded independent research institutions. These research institutions are also commonly known as federal laboratories [5], of which 17 national laboratories of the Department of Energy are often called the US National Laboratories. The main national research institutions in Germany are the Max Planck Society, the Helmholtz Research Association, and the Fraunhofer Society. The Max Planck Society is mainly engaged in multidisciplinary and interdisciplinary basic research. The Helmholtz Research Federation has 16 national large-scale research centers, which mainly use large-scale equipment to carry out interdisciplinary forward-looking research on energy, earth and environment, medical health, key technology, material structure, and transportation and aerospace [6]. Franhoff Society undertakes the bridge between basic research and industrial technology development. On the one hand, it is engaged in the basic research of high technology for application, on the other hand, it also develops high-tech achievements that can be put into production by industry.

(2) Commonalities of national research institutions and their differences from university/enterprise R&D institutions. Although national research institutions in major countries have different organizational forms, missions, and objectives, they have some commonalities. ① Carry out the organized and long-term research in national security and strategic fields, such as military science and technology, nuclear energy, space, and agricultural science and technology. ② Carry out the research that is significant to the country but expensive with great risks. This kind of research requires unique scientific facilities and professional staff, which often beyond the capability of private enterprizes and universities, such as nuclear fusion. ③ Carry out the research on technology with a large scale and long time, which is difficult for private enterprises to bear, such as coal gasification and liquefaction. ④ Carry out the research that is of great significance to the economic and social development of the whole country, but the research department cannot directly obtain economic benefits, such as industrial measurement standards, public health and health care, and social and occupational safety. ⑤ Carry out the sensitive confidential research and security research [5,7,8]. These characteristics distinguish national research institutions from universities and enterprise R&D institutions. Moreover, the research tasks of national research institutions are oriented to the strategic needs of the country, shouldering the mission and orientation, such as national security, energy research, environmental quality, and public health. Compared with national research institutions, universities carry out non-oriented and free exploratory research. The research is generally performed by small research groups composed of teachers and students, and the facilities used are not large enough to carry out large-scale scientific research projects. In addition, due to the high mobility of University researchers, the campus cannot be regarded as an ideal place to manage long-term research or lasting and labor-intensive experiments. Enterprise R&D institutions are generally oriented to the profitable research work, rather than the social and national interests [5].

(3) Characteristics of disciplines and R&D activities of national research institutions.① National research institutions engaged in research and development in the national strategic fields are facing comprehensive and long-term strategic scientific problems. They generally need a multidisciplinary and interdisciplinary foundation and have the comprehensive ability from foundation and application to technological development. For example, according to its strategic objectives, NASA has deployed the research work of four subject groups of science, aeronautics research, exploration system, and space operation, including a number of related project groups of multiple disciplines, from foundation to application, and from science to technology [8]. ② Some long-term and powerful national research institutions not only have strong capabilities in applied research and technological development, but also have strong strength in basic research. For example, since 1950, Lawrence Berkeley National Laboratory has produced 20 Nobel Prize winners, and Brookhaven National Laboratory has produced 19 ③. ③ National research institutions have advanced layout in the emerging fields, which provides sources for the whole research community to open up new directions and sustainable driving force for development. For example, national laboratories such as Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory in the US began to deploy biomedical research after World War II to study the effects of nuclear radiation on human body. Decades of research accumulation laid the foundation for the Human Genome

---

① Government-owned and government-operated (GOGO) forms, such as NIH internal research institutes and NASA research centers

② Government-owned and contractor-operated (GOCO) forms, such as most national laboratories under the US Department of Energy.

③ Office of Science, the US Department of Energy. DOE Nobel Laureates. [2022-05-02]. https://science.osti.gov/About/Honors-and-Awards/DOENobel-Laureates.

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

Project firstly initiated by the US Department of Energy in 1990 and launched in cooperation with NIH.

(4) Institutionalized characteristics of national research institutions as national strategic sci-tech strength. To sum up, as the national strategic sci-tech strength, national research institutions are institutionalized forces that invest and deploy in important fields of national development (such as national security, aerospace, strategic technologies and industries, and important social welfare fields), and have gathered a group of excellent sci-tech personnel. Taking national goals and interests as the mission, national research institutions shoulder the responsibility of solving major sci-tech problems that restrict the overall development and long-term interests of the country under the guidance of national strategic needs. As the source of original innovation and disruptive technology, national research institutions carry out the organized, basic, strategic, and forward-looking research with multi-disciplinary, multi-field, and long-term characteristics. They have five institutionalized characteristics as follows. ① Tackling strength. Focusing on the significant needs of the country, national research institutions have the ability to tackle major difficulties in science and technology. ② Multidisciplinary comprehensiveness. With a multi-disciplinary foundation, national research institutions absorb the advantages of multi-disciplinary integration and carry out research on complex and comprehensive scientific issues and those in major social challenges. ③ Long term and sustainability. National research institutions have the ability to continuously accumulate and make breakthroughs in important fields. ④ Leading role. National research institutions have the ability to grasp the frontier direction of sci-tech development and make breakthroughs in the frontier direction, thus leading the development of the entire field as well as the research organization and cultural construction. ⑤ Organizational strength. National research institutions have the ability to organize all team members and other units to jointly tackle difficulties and deal with emergencies.

2 Role and successful experience of China's national research institutions in promoting sci-tech development and meeting national strategic needs

The science and technology had a quite weak foundation when the People's Republic of China (PRC) was found. Facing the urgent needs of national economic construction, social development, and national defense construction, it was essential for the CPC and China to rapidly establish a sci-tech team that brought together sci-tech resources and solved the key problems of national development, thus developing China's science and technology. Under this circumstance, Chinese Academy of Sciences (CAS) was established, and then a number of national research institutions were established successively in the fields of national defense, aviation, important industries, agriculture, and social development. Guided by national strategic needs, these national research institutions have solved major scientific problems in various important fields of national development, overcome key technological problems, and become national strategic sci-tech strength that promoted China's scientific, technological, economic, and social development and safeguarded national security. After the reform and opening-up, China's national research institutions have undergone reform, transformation, and development. A bunch of national research institutions that have made great contributions to China's scientific, technological, economic, and social development have been transformed into enterprises or research institutions in enterprises. CAS, Chinese Academy of Agricultural Sciences, Chinese Academy of Medical Sciences and other research institutions have made continuous progress in reform and opening-up, and continue to play the role of national strategic sci-tech strength in meeting national strategic needs.

2.1 China's national research institutions as national strategic sci-tech strength

2.1.1 Role of CAS in promoting sci-tech development and meeting national strategic needs

In the early stage of the construction of the PRC, according to the deployment of the CPC and the country, CAS, as the center of national research [9], assumed the responsibility of leading the development of national science and technology. CAS has established a number of research institutes to gather research teams to serve economic construction and national development. Among them, some institutes were set up and developed based on the major needs of national development. For example, the primary research direction of the Institute of Mechanism, CAS fully reflected the national needs. It laid out the initial research on rocket, missile, and artificial satellite [10].

In the formulation and implementation of the 1956–1967 Long Range Development Program of Sciences and Technology (hereinafter referred to as the Twelve-Year Plan), CAS played a leading and backbone role [11]. In 1956, the state implemented the Four Emergency Measures. CAS quickly gathered its strength in the four emerging key technology areas, including radio, automation, semi-conductor, and calculation technology, which laid a foundation for China to catch up with the advanced international level in a short time. In the development of "Two Bombs, One Satellite", which established China's status as a major country, CAS mainly undertook a series of key sci-tech tasks in the development of atomic bombs and missiles, making significant contributions to China's "Two Bombs, One Satellite" project. In particular, several generations of computers developed by CAS in the Four Emergency Measures made outstanding contributions to the successful development of atomic bombs

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

and hydrogen bombs [12]. Since the reform and opening-up, CAS has been playing the key and leading role in strategic sci-tech strength, and has been at the forefront of the reform and opening-up, thereby creating plenty of "initial" achievements in the reform and opening-up of China's sci-tech fields (for example, CAS initially set up a national science foundation, initially advocated the establishment of the national 863 Program, initially set up the first research institute in the PRC, and initially implemented the degree system). Outstanding achievements have been made in advancing scientific frontiers, fulfilling significant needs of the country, serving the main economic battlefields, and building talent teams [13].

2.1.2 Role of the Fifth Research Institute of the Ministry of National Defense in promoting the development of China's space industry

In 1956, the Fifth Research Institute of the Ministry of National Defense was established, marking the beginning of the development of China's space industry. In the second year of its establishment, the Fifth Research Institute of the Ministry of National Defense established two branches: the First Branch (known as China Academy of Launch Vehicle Technology nowadays), including eight research departments of overall design, structural strength, aerodynamics, rocket engine, ramjet, chemical propellant, material research and testing, and the Second Branch, which is a research institution specializing in missile control system. In September 1961, the Third Branch of the Fifth Research Institute of the Ministry of National Defense was established, which is now the China Aerospace Science and Technology Research Institute of China Aerospace Science and Industry Corporation. In July 1962, the Fifth Research Institute of the Ministry of National Defense established China's first solid rocket motor research institute in Luzhou, Sichuan. In April 1964, it was renamed the Fourth Branch of the Fifth Research Institute of the Ministry of National Defense. In December 1964, the Seventh Ministry of Machinery Industry was established on the basis of the Fifth Research Institute of the Ministry of National Defense. The First Branch of the Fifth Research Institute of the Ministry of National Defense was then renamed the First Research Institute of the Seventh Ministry of Machinery Industry. Later, it was renamed the First Research Institute of the Ministry of Aerospace Industry, the First Research Institute of the Aerospace Industry Corporation, and the First Research Institute of China Aerospace Science and Technology Corporation, also known as the China Academy of Launch Vehicle Technology. In 1962, Academy of Aerospace Solid Propulsion Technology (also known as the "Fourth Aerospace Academy") was established, which was the largest and most powerful base for the basic theoretical research, design, development, production, and tests of the solid rocket motor in China. In 1968, China Academy of Space Technology was established, namely the Fifth Research Institute of the Seventh Ministry of Machinery Industry, which was the main research center of China's space technology and the base for spacecraft development and production. Thereafter, the Seventh Ministry of Machinery Industry was renamed the Ministry of Aerospace Industry, the Ministry of Aerospace Industry, and then split into Aviation Industry Corporation of China, Ltd. and China Aerospace Industry Corporation (China National Space Administration). Until 1999, the current China Aerospace Science and Technology Corporation and China Aerospace Science and Industry Corporation Limited were established on the basis of some enterprises and units affiliated to the former Aerospace Industry Corporation [14].

The establishment and development of the Chinese Academy of Aerospace Engineering, starting from the Fifth Research Institute of the Ministry of National Defense, has brought about the start, development, and maturity of technologies in various fields of aerospace. It has not only contributed to China's "Two Bombs, One Satellite" cause, but also made great contributions to a series of development, including launch vehicle, scientific satellite, recoverable satellite, communication satellite, meteorological satellite, remote sensing and resource satellite, Beidou satellite navigation system, progress of China's lunar exploration project, and manned aerospace project [15].

2.2 Achievements and successful experiences of national research institutions in facing national strategic needs in recent ten years

Over the past decade, China's sci-tech strength is moving from quantitative accumulation to qualitative leap, from point breakthrough to system capability improvement, and sci-tech innovation has made new historic achievements. CAS and other national research institutions have played an important role in fulfilling the significant needs of the country, targeting the global sci-tech frontier, serving the main economic battlefields, and benefiting people's life and health.

2.2.1 Fulfilling the significant needs of the country and strongly supporting the national strategic tasks

(1) Science and application of manned spaceflight and lunar exploration projects. CAS is one of the initiators and organizers of China's manned spaceflight and lunar exploration projects, as well as the proposer and implementer of scientific and application goals. More than 50 affiliated units have undertaken a large number of important engineering tasks and collaborative supporting tasks in the manned spaceflight and lunar exploration projects, breaking through a large number of key technologies and providing strong sci-tech support for the implementation of the project. Tiangong II has completed 14 experiments in three major scientific fields, and made outstanding scientific progress. In the lunar exploration projects, CAS has successfully accomplished the projects of the development and scientific exploration of Chang'e-1, 2, and 3.

(2) Development of Beidou Navigation Satellite System

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

series satellites. Beidou Navigation Satellite System is a global navigation satellite system built and operated independently by China, compatible with other systems in the world and public. As one of the main construction units, CAS has organized 14 units to undertake the development tasks of Beidou-2, global system test satellite, and Beidou-3 global networking satellite, leading the leap-frog development of China's advanced satellite technology and contributing to the global networking of Beidou Navigation Satellite System [16].

(3) Deep-sea equipment, technology, and exploration. In recent years, as national strategic sci-tech strength, China's national research institutions have carried out in-depth research on key technologies in the field of deep-sea equipment and technology, and made various sci-tech achievements represented by Jiaolong, Deep-sea Warrior, and Striver, leading the leap-frog development of China's deep-sea science and technology. The deep-sea manned submersible, Striver, broke the 10 000-meter milestone for eight times in the Mariana Trench, the deepest depth in the world, and set a national diving record of 10 909 meters. China Ship Scientific Research Center (702 Research Institute of China State Shipbuilding Corporation Limited) took the lead in the overall design and integrated construction of the Striver, and the Institute of Deep-sea Science and Engineering of CAS organized the sea trial as the owner. The Striver and other sci-tech engineering tasks have realized the large team cooperation of national sci-tech strength across systems, units, and departments. It is a vivid practice for China to give full play to the institutional advantages of pooling all resources to accomplish major tasks, thus exploring a new system concentrating nationwide effort and resources on key national sci-tech undertakings [17].

2.2.2 Serving the main economic battlefields and benefiting people's life and health

In recent years, CAS has made a number of major sci-tech achievements in agricultural science and technology, core technologies and industrial demonstrations of clean and efficient utilization of coal, nonlinear crystal materials and equipment, stem cell and regenerative medicine research, new drug development, resource and ecological environment, disaster prevention and mitigation, etc. The transformation demonstration project has taken root with significant economic and social benefits. For instance, in terms of the clean and efficient utilization of coal, CAS has broken through the engineering technical difficulties of indirect coal liquefaction, and successfully applied it to the world's largest single set of 4 million tons/year coal-to-liquids project. CAS has firstly achieved the industrialization of coal-to-olefins in the world, and successfully developed a complete set of industrialized technologies for methanol-to-olefins (DMTO) and completed its industrial application. CAS has developed the coal-burning technology of circulating fluidized bed with high efficiency and low pollution, and realized ultra-low emission of nitrogen oxides by directly burning coal, burning semi coke, and burning residual carbon. For another example, a series of original achievements have been made in the field of stem cells and regenerative medicine, a number of core technologies with independent intellectual property rights have been established, and a large number of preclinical and clinical research work have been carried out using these technologies, achieving great results ④.

2.2.3 Vigorously supporting national emergency and safety management

The outbreak of COVID-19 has posed a serious threat to people's health and economic and social development in China, which has become a major emergency issue related to national strategic security. In response to the COVID-19, the State Council has established a research team on the joint prevention and control mechanism for the COVID-19 (hereinafter referred to as the research team) to urgently start vaccine development and give play to the advantages of the new system concentrating nationwide effort and resources on key national sci-tech undertakings. In January 2020, the research team deployed five main technical routes, involving inactivated vaccines, adenovirus vector vaccines, recombinant protein vaccines, vaccines using attenuated influenza virus vectors, and nucleic acid vaccines, and selected 12 teams to support the promotion. Most of the 12 teams for novel coronavirus vaccine R&D were national strategic sci-tech strength supported by the national science and technology plan for a long time. As national research institutions, they demonstrated the strategic sci-tech strength. CAS, Academy of Military Medical Sciences, Chinese Academy of Medical Sciences, and other research institutions gathered multi-disciplinary platforms such as virus isolation, antigen design, animal model construction, *in vivo* and *in vitro* evaluation, and quality verification to provide common technical support, and quickly applied the research results to vaccine R&D, significantly supporting China's global leadership in the progress of novel coronavirus vaccine R&D. As of April 2021, 19 vaccine varieties across the country have been approved for clinical research, covering all five technical routes. From launch to approval, the "Chinese speed" of novel coronavirus vaccine R&D is not only much faster than the usual 5–18 years, but also exceeds the 12–18 month vaccine R&D cycle in the pandemic situation [18].

2.2.4 Promoting the development of the frontier of science and technology

In terms of basic research, the research teams of the Institute of Physics of CAS and the University of Science and Technology of China have made major breakthroughs in

④ Chinese Academy of Sciences. 率先行动砥砺奋进——"十八大"以来中国科学院创新成果展. [2022-05-02]. http://cxcj.cas.cn/ccg/mxgmjjzzc/fwrkyjk.

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

iron-based superconductivity, which have won the first prize of the 2013 National Natural Science Award. In 2012, the international research team led by the Institute of High Energy Physics of CAS found a new mode of neutrino oscillation in the neutrino experiment of Daya Bay reactor, and accurately measured the neutrino mixing angle θ_{13}. This important achievement was a new understanding of the basic laws of the material world, and was selected into the Top Ten Breakthroughs in the Year 2012 of *Science*. In 2017, the Center for Excellence in Brain Science and Intelligent Technology of CAS took the lead in overcoming the problem of cloning monkeys from non-human primates, and artificially created single-chromosomal eukaryotic cells for the first time, which was another breakthrough in the field of cloning biotechnology after the cloning of sheep "Dolly" in the UK in 1997. In 2016, the Five-hundred-meter Aperture Spherical Radio Telescope (FAST, also known as China Sky Eye) built by CAS was the world's largest single-aperture and most sensitive radio telescope with China's independent intellectual property rights. The millisecond pulsar first discovered by it was internationally certified in April 2018, opening a new era of pulsar discovery by China's radio telescope [16].

2.3 Successful experience of national research institutions in meeting national strategic needs

In terms of meeting the national strategic needs, the main successful experiences of national research institutions are as follows.

(1) Have strong organization and leadership. "Two Bombs, One Satellite" has created a new system of pooling national resources and strengths to overcome key technological problems. Strong leadership is the key to success. This spirit and mode will continue to be maintained and carried forward in China's aerospace industry, forming a top-down system for decision-making, management, and research with the characteristics of smooth from top to bottom, strict management, and strong leadership. This provides organizational guarantee for a series of major breakthroughs in China's space industry [15]. In the recent campaign to fight against the COVID-19 and develop a novel coronavirus vaccine, the strong leadership was proved to be the guarantee of success.

(2) Aim at strategic sci-tech issues with a long-term view. National research institutions should solve the important sci-tech problems in the current national development. In addition, they should focus on the long term, aiming at the strategic sci-tech problems that support the long-term development of the country. We should deploy strategic basic research and cutting-edge technologies in advance, continue to tackle key problems, and enhance the foundation and ability of science and technology to support the country's development.

(3) Adhere to independent innovation as the strategic basis for sci-tech development. In the key fields of national development, we can only rely on ourselves to acquire key and core technologies. We should insist on independent innovation and vigorously develop key and core technologies with independent intellectual property rights. The achievements of China's manned spaceflight industry fully demonstrate the importance of insisting on independent innovation.

(4) Give full play to the gathering and coordination ability of institutionalized teams. In tackling key technologies, it is necessary to give full play to the institutionalized advantages of strategic sci-tech strength. In terms of manned spaceflight and lunar exploration projects and the development of Beidou Navigation satellite System series satellites, CAS has organized dozens of units to undertake a large number of important engineering tasks and cooperative supporting tasks, breaking through a large number of key technologies. The achievements in deep-sea equipment, technology, and detection were jointly accomplished by the units across the country, including the China Ship Scientific Research Center and the Institute of Deep-sea Science and Engineering of CAS.

(5) Put people first and stimulate the creativity and vitality of sci-tech talents. Sci-tech talents are the first driving force for the sci-tech cause. We should attract and gather outstanding talents with a global perspective, stimulate the enthusiasm and creativity of talents with national honor and sense of mission, create a good environment, and cultivate and bring up leading sci-tech talents.

(6) Adhere to reform and innovation as the driving force. We should follow the laws of sci-tech development and innovation activities, learn from advanced international experience, break the shackles of obsolete ideas, systems, and mechanisms, promote the construction of the governance system of research institutes with Chinese characteristics, reform and improve the organization and implementation mode of major research projects, and promote the reform of sci-tech appropriation system and personnel system.

3 Ideas and policy suggestions for strengthening the construction of national research institutions

At present, in the face of great changes that have not been seen in the world in a century, especially the increasing international competition situation and the critical period of transformation and upgrading of China's economic and social development, we need to focus on solving a number of major strategic sci-tech problems that affect and restrict the overall development and long-term interests of the country, and use science and technology to provide solid support for the long-term development of the country. Therefore, it is necessary to strengthen the role of national research institutions, maintain a strong research team focusing on research and innovation in the national strategic field, and give full play to the advantages of institutionalization, systematization, and

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

integration of national research institutions. National research institutions should play a core and crucial role in overcoming major scientific problems, tackling key technical problems, and providing scientific support for major economic and social development issues, thus driving the development of the whole national strategic sci-tech strength, and improving the overall efficiency of the national innovation system.

(1) At the level of national strategy, strengthen top-level design and clarify strategic orientation. Under the guidance of self-reliance and self-improvement in science and technology, we should focus on national strategic needs and strengthen the strategic deployment of sci-tech innovation in key areas of national economic and social development and national security. We should determine the key technical fields to solve the current development bottleneck, the key cultivation and development direction for future development, as well as the specific major tasks, and form a clear sci-tech goal orientation. We should establish a mechanism for national strategic sci-tech strength to undertake major national sci-tech tasks, establish appropriate R&D systems and organizational models, give play to the backbone and leading role of national research institutions, and build the main force of national strategic sci-tech strength.

(2) At the level of national research institutions, promote reform and development. ① Clarify the mission orientation of national research institutions. We should stably support a group of national research institutions in forward-looking, basic, and strategic research fields, clarify their mission orientation and functions, and make them focus on their mission and objectives in terms of resource allocation, organizational model, and operating mechanism. ② Promote the reform and reconstruction of the research system of national research institutions. According to the functional orientation of research institutions, we should scientifically and rationally distribute research forces, reform and reshape research organization units, and enhance core competence and collaborative innovation. ③ Deepen the institutional reform of national research institutions. We should reform the operating mechanism of research institutions, establish a modern research institution system, and improve the corporate governance structure. Moreover, we should promote the reform of fund allocation, personnel system, and income distribution system. In terms of subject selection, fund use, personnel allocation, and reward system, more autonomy should be given to research institutions, with giving "special policy" to some extent, so that research institutions can flexibly allocate resources according to the rapidly changing situation of sci-tech development and the changes of international competition. ④ Establish a goal-oriented mechanism in institutional performance evaluation and dynamic adjustment. Taking the performance of research institutions as one of the main basis for support in the next year, a competition and adjustment mechanism will be formed within and among national research institutions.

(3) Strengthen the cooperation between national research institutions with research-oriented universities and leading sci-tech enterprises, and improve the overall capability of the national strategic sci-tech strength system. Surrounding the national strategic objectives, we should enhance collaboration among various subjects of the national strategic sci-tech strength, form a cross-agency and cross-field network for innovation and cooperation, improve the overall capacity and efficiency of the national strategic sci-tech strength, and promote the overall efficiency of the national innovation system. National research institutions should strengthen cooperation with high-level research-oriented universities, and rely on strategic sci-tech tasks to carry out cooperative research and joint training of talents with universities. They should also strengthen cooperation with leading science and technology enterprises, effectively utilize their advantages of technological competitiveness perception, and jointly carry out R&D of key industrial common technologies, and transformation and industrialization of sci-tech achievements.

References

1 Keck O. The German national system for technological innovation//National Innovation Systems: A Comparative Analysis. Translated by Zeng G P, Liu X L, Wang C W, et al. Beijing: Intellectual Property Publishing House, 2012: 138–196 (in Chinese).

2 Dupree A H. Science in the Federal Government: A History of Policies and Activities to 1940. Baltimore: Johns Hopkins University Press, 1964.

3 Fan C L. Evolution of strategic scientific and technological power: The world and China. Bulletin of Chinese Academy of Sciences, 2021, 36 (5): 533–543 (in Chinese).

4 President's Council of Advisors on Science and Technology. Transformation and opportunity: The future of the U.S. research enterprise. (2012-11-30) [2022-04-04]. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast_future_research_enterprise_20121130.pdf.

5 Neal H A, Smith T L, McCormick J B. Beyond SPUTNIK: U.S. Science Policy in the Twenty-First Century. Translated by Fan C L, Li S M. Beijing: Peking University Press, 2017 (in Chinese).

6 The Development of the German National Laboratory System: Previous and Present Life of the Helmholtz Association of German Research Centres. Translated by He H, Xu R, Huang Q, et al. Beijing: Science Press, 2019 (in Chinese).

7 Li M D. Review of American Science and Technology. Beijing: Social Sciences Academic Press, 1992 (in Chinese).

8 Bai C L. A Profile of the World's Major National Scientific Research Institutions. Beijing: Science Press, 2013 (in Chinese).

9 Hu W J. The Central Committee of the Communist Party of China to the report of the Leading Party Group of the Chinese Academy of Sciences on the basic situation of the current work of the academy and its future tasks to the Central Committee(March 1954)//Selected materials on the Science and Technology Policy's Republic of China (1945–1995). Jinan: Shandong Education Press, 2006 (in Chinese).

10 Liu G J. Strenthening national team of mechanics by benchmarking and upholding fine traditions. Bulletin of Chinese Academy of Sciences, 2021, 36 (Z2): 5–12 (in Chinese).

11 Fan H Y. The role that history assigned to the people of Chinese Academy of Sciences. Science & Culture Review, 2014, 11 (6): 5–23 (in Chinese).

12 Zhang J F. Please remember them: memories of the Chinese Academy of Sciences and "two bombs and one star". (2015-08-03) [2021-03-30]. http://news.sciencenet.cn/htmlnews/2017/6/378921.shtm (in Chinese).

13 Bai C L. Pioneer of reform and openning-up, engine of innovative development—40 years of the Chinese Academy of Sciences since reform and opening-up. Bulletin of Chinese Academy of Sciences. 2018, 33 (12): 1277–1281 (in Chinese).

14 Wu M. From the fifth institute of the ministry of national defense to the

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.

aerospace group: history of Chinese Aerospace Institutes. (2013-10-08)[2022-05-08]. https://history.sohu.com/20131008/n387670242.shtml (in Chinese).
15 Li C Z. Breakthroughs in China's space technology. Bulletin of Chinese Academy of Sciences, 2019, 34 (9): 1014–1027 (in Chinese).
16 Chinese Academy of Sciences. 40 Years of the Chinese Academy of Sciences Since Reform and Opening-up. Beijing: Science Press, 2019 (in Chinese).
17 Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences. Led the organization of "Striver" totackle key problems and sea trials to scale the peak of deep-sea science and technology. Qizhi, 2020, (12): 64–65 (in Chinese).
18 Zhang X M. Construction of China's strategic science and technology forces from research and development of COVID-19 vaccine. Bulletin of Chinese Academy of Sciences, 2021, 36 (6): 709–715 (in Chinese).

(Translated by CAI WX)

FAN Chunliang, research professor of the Institutes of Science and Development, Chinese Academy of Sciences (CAS). He is also faculty at School of Public Policy and Management, University of Chinese Academy of Sciences. His research focuses on science and technology policy and management. In 2005, he published a monograph Science and Technology Policy in the Era of Globalization. E-mail: fcl@casisd.cn

CNKI

© 2022 China Academic Journals (CD Edition) Electronic Publishing House Co., Ltd.