Bulletin of Chinese Academy of Sciences 院刊

Volume 37 | Issue 3 Article 6

3-20-2022

Strategic Development Problems and Mechanism Improvement in Engineering Science

Peinan LI
Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China, lipeinan@casisd.cn

See next page for additional authors

Recommended Citation

LI, Peinan; BAO, Weimin; and YAO, Wei (2022) "Strategic Development Problems and Mechanism Improvement in Engineering Science," *Bulletin of Chinese Academy of Science Version)*: Vol. 37 : Iss. 3 , Article 6.
DOI: https://doi.org/10.16418/j.issn.1000-3045.20220210002
Available at: https://bulletinofcas.researchcommons.org/journal/vol37/iss3/6

Strategic Development Problems and Mechanism Improvement in Engineering Science

Abstract

Modern engineering embodies the characteristics of multi-disciplinary integration and is the engine for the development of basic science and engineering technology. Engineering science comes from engineering and serves engineering. Engineering science and natural science both belong to the category of basic research and are the basis of jointly supporting the development and progress of engineering technology. To this end, this paper reviews the development process of engineering science, and on the basis of fully grasping the and the connotation, development stage and modern characteristics of engineering science, draws on the experience and practices of major countries in the development of engineering science, and proposes policy recommendations for resolving the outstanding problems and deficiencies in the current development of engineering science.

Keywords

engineering science; development strategy; thoughts and suggestions

Authors

Peinan LI, Weimin BAO, and Wei YAO

Citation: LI Peinan, BAO Weimin, YAO Wei. Strategic Development Problems and Mechanism Improvement in Engineering Sciences [J]. Bulletin of Chinese Academy of Sciences, 2022 (3).

Strategic Development Problems and Mechanism Improvement in Engineering Sciences

LI Peinan[1], BAO Weimin[2], YAO Wei[3]

1. Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China;
2. China Aerospace Science and Technology Corporation, Beijing 100048, China;
3. Qian Xuesen Laboratory of Space Technology, China Academy of Space Technology, Beijing 100094, China

Abstract: Modern engineering embodies the characteristics of multi-disciplinary integration and is the engine for the development of basic sciences and engineering technology. Engineering science comes from engineering and serves engineering. Engineering sciences and natural sciences both belong to the category of basic research and are the basis of jointly supporting the development and progress in engineering technology. This paper reviews the development process of engineering sciences and interprets the connotation, development stages, and modern characteristics of engineering sciences. On this basis, it draws on the experience and practice of major countries in the development of engineering sciences and proposes policy recommendations for resolving the outstanding problems and deficiencies in the current development of engineering sciences. **DOI:** 10.16418/j.issn.1000-3045.20220210002-en

Keywords: engineering science; development strategy; thoughts and suggestions

Modern engineering has a profound impact on the social development process. Every significant breakthrough in engineering technology results in the global scientific and technological revolution and industrial change and generates many industrial powers. “A new round of revolution and transformation in science, technology, and industries is reconstructing the global innovation layout and reshaping the global economic structure.” [1, 2] Engineering sciences and natural sciences are the theoretical basis of modern engineering. In recent years, the difficulty and complexity for people to conduct engineering activities become more prominent with the continuous improvement in social productivity, which makes the modern engineering sciences develop toward systematization, coordination, and socialization. Meanwhile, engineering sciences constantly improve the complexity and precision of scientific research and gradually change to the “big science” model [3–6], which greatly enhances the ability of human beings to understand nature.

Engineering sciences involve all aspects of production and life in terms of the national conditions of China, supporting the development of the national economy and defense construction. They are important foundations in promoting the construction of a modern socialist country in all respects and realizing the Chinese Dream of national rejuvenation. The research on engineering sciences in China, however, still has many shortcomings and deficiencies. In 2014, General Secretary Xi Jinping pointed out at the 17th Academician Meeting of the Chinese Academy of Sciences (CAS) and the 12th Academician Meeting of the Chinese Academy of Engineering (CAE) that “there has been a chronic disease in China for many years, namely that the transformation of scientific and technological achievements into practical productivity is not effective, successful, and smooth.” [7] One of the main reasons is that the research on engineering sciences is relatively lagging behind the rapid development of modern industries. Although the investment in basic research in China has been increasing, and the scale and variety of industrial production are expanding, studies of engineering sciences, an important foundation of industrial development [8], see no significant progress and breakthrough in scientific principles, scientific issues, scientific thinking, and scientific research paradigms, which has become the weak link of the science and technology innovation chain in China. In 2021, General Secretary Xi Jinping further pointed out at the 20th Academician Meeting of CAS, the 15th Academician Meeting of CAE, and the 10th National Representatives Meeting of China Association for Science and Technology that “we should vigorously strengthen the multi-disciplinary research on modern engineering and technological sciences to drive the development of basic sciences and engineering technology and thus form a complete modern science and technology system.”

This study reviews the development history of engineering sciences and fully understands their connotation, development stages, and modern characteristics. From the perspective of engineering roots and service engineering, it focuses on the major engineering needs of the country and draws lessons from the experience and practice of major countries in developing engineering sciences to discuss the common scientific problems in engineering technology. It is of great significance for us to seize the opportunity of a new round of

Received: 2022-3-11
Supported by: Consulting Project of the Academic Divisions of the Chinese Academy of Sciences (2021-ZW02-W-003)

revolution and transformation in science, technology, and industries, promote scientific and technological innovation with engineering sciences, accelerate the construction of China into a science and technology giant, and strengthen high-level science and technology.

1 Connotation, development stages, and modern characteristics of engineering sciences

Engineering sciences are the summary, refinement, and sublimation of human knowledge on the transformation of natural means and methods in production practice, which plays the most direct role in promoting the development of productivity. Tracing back to the emergence and development of several industrial revolutions and the application of representative inventions can provide an important basis for us to accurately grasp the connotation, development stages, and modern characteristics of engineering sciences.

1.1 Connotation of engineering sciences

Qian Xuesen's lectures on engineering and engineering sciences at Zhejiang University, Jiao Tong University, and Tsinghua University in 1947 and his papers published in 1948 all clarified the scientific connotation and importance of engineering sciences [9, 10]. In the 1950s, Qian Xuesen proposed the idea of technological sciences, emphasizing that the three knowledge departments of natural sciences, technological sciences, and engineering technology should advance at the same time and influence and support each other [11, 12].

As QIAN Xuesen [13] pointed out in *Engineering and Engineering Science* that "an independent discipline system has been formed between science and engineering technology, and that is engineering sciences." He believed that natural science research mainly aims at discovering and mastering the basic laws of the existence and development of nature. Engineering sciences are the general laws of engineering technology and the comprehensive knowledge system used in engineering compared with natural sciences. In other words, natural sciences are for the understanding of nature, and engineering sciences are for the use and transformation of nature. Driving the development of natural sciences through engineering sciences can not only help natural sciences obtain more scientific discoveries, scientific principles, and technological creation but also effectively transform and apply the achievements of natural sciences.

1.2 Development stages of engineering sciences

The review of the course of the industrial revolution history indicates that the formation and development of engineering sciences are inseparable from natural sciences, and in fact, they complement and promote each other.

In the 1760s, the first Industrial Revolution began in Britain. The invention and use of steam engines made large machine production become the main means of industrial production. The principles of science and technology in natural sciences were widely applied and instructed people to conduct engineering activities, which provided an important basis for the establishment of engineering sciences. Meanwhile, the production practice of the first Industrial Revolution also gave birth to thermodynamics, an important branch of physics. Engineering sciences entered the development stage of simple mechanical power in this period.

In the 1870s, the invention and application of electric power triggered the second Industrial Revolution centered on electric power. The production means with steam engines as the main mechanical power had been replaced by the production means of electrical appliances and internal combustion engines, and human beings had ushered in the electrical era. In this period, various new technologies and inventions emerged one after another and were widely used in industrial production. Emerging industries, such as electric power, petroleum, chemical industry, and automobiles, required large-scale centralized social production. Engineering sciences had been continuously developed and improved in such production and entered the stage of modern development.

In the 1940s, the third Industrial Revolution had been triggered by the invention and application of atomic energy technology and computer technology, as well as the emergence of advanced technologies, such as synthetic materials, molecular biology, genetic engineering, space technology, and marine technology. This indicated that human society had entered another higher information age from the era of mechanization and electrification. Engineering sciences had entered the development stage of modern engineering sciences based on information technology, new material technology, new energy technology, and life science technology and marked by the integrated development of materials, energy, and information in this period.

These cases of technological inventions and engineering activities of the Industrial Revolution demonstrate that the development of engineering sciences can greatly improve the scale and level of national and regional industries. More importantly, countries and regions can also obtain more new discoveries, inventions, theories, paradigms, and creation of natural sciences, engineering sciences, and engineering technology and cultivate many scientists with innovative thinking in the new round of revolution and transformation in science, technology, and industries since the 21st Century. It is of far-reaching significance to drive the development of natural sciences through engineering sciences.

1.3 Modern characteristics of engineering sciences

As mentioned above, engineering sciences are basic sciences with rich scientific connotations and technical content and are closely combined with social production. Modern engineering sciences have been developing and absorbing the scientific elements and theoretical essence of other disciplines, mainly presenting three important characteristics.

(1) The development of large-scale socialized production toward systematization and coordination determines that engineering sciences have systematic characteristics. Engineering sciences are always closely related to the production field in the process of emergence and development, which aim to solve the theoretical problems of how to apply science and technology to the production field. From a practical point of view, engineering activities and industrial production often involve many system elements with different characteristics and properties. Therefore, it is necessary for engineering sciences to analyze and judge these elements first and then organize engineering activities with the theories and methods of system sciences. In this way, an engineering entity with specific functions in line with the production purposes can finally be formed. Specifically, engineers will conduct a systematic and comprehensive analysis according to the engineering requirements and put forward the feasibility, implementation approaches, and risk resolution measures of an engineering scheme to provide a scientific and effective scheme for engineering implementation. The system engineering method is used for realizing the overall optimization rather than pursuing the optimization of a single element.

(2) Engineering sciences can manage, improve, and implement complex engineering with the development of times and the progress in science and technology, which determines that engineering sciences have the characteristics of complexity. Qian Xuesen [13] pointed out in *Engineering and Engineering Science* that "the service provided by an engineering scientist can clarify highly confusing engineering problems and can be used to avoid more errors in engineering design." At present, modern engineering sciences have entered a new period of development, organization, and operational management of complex systems based on a new round of revolution and transformation in science, technology, and industries. In this change, the professional theory and practice of traditional engineering sciences are also developing. For instance, in the development and construction of modern complex engineering systems, modern engineering sciences often require relevant research or staff to not only use cutting-edge technologies to make scientific and quantitative research and judgments on the basic characteristics of complex system engineering but also improve the development and construction of complex engineering systems through long-term operation and iterations.

(3) The scope of modern engineering activities and the continuous expansion of disciplines determine that engineering sciences have the characteristics of comprehensiveness and intersection. A specific engineering activity or engineering object often involves different scientific fields, which has long gone beyond the coverage of the traditional industrial field. Therefore, it is necessary to unite scientists in different fields to solve the same system engineering problem and achieve application innovation in cross integration to form a comprehensive system integrating scientific activities, technical activities, social activities, management activities, and cultural activities. For example, China's Three Gorges Project is a typical product of multi-disciplinary comprehensive innovation, which involves geology, water conservancy, architecture, electric power, materials, ecology, economics, sociology, and other disciplines. Hence, the project can not only meet the needs of social development but also give play to great economic benefits. People begin to reflect on the purpose and means of science and technology at the philosophical level as the problems of ecological security and ethics involved in the project operation become more and more prominent. As a result, engineering philosophy [14], a new interdiscipline, came into being in the cross integration of engineering sciences and philosophy. The continuous development of engineering philosophy answers the questions of "what are engineering sciences" and "what do we need engineering sciences to do" from the aspects of theory and cognition, which promotes the further development of engineering sciences.

2 Development needs of engineering sciences and existing prominent problems

Engineering sciences are a research field of basic sciences that meets the requirements of modern engineering development and are differentiated from and independent of modern sciences. Engineering sciences will be oriented to the forefront of world science and technology, the main battlefield of economy, major national needs, and people's life and health. They focus on the basic and core areas of national strategic security such as aerospace, nuclear industry, information, artificial intelligence, and advanced manufacturing, as well as frontier science and technology and industrial transformation fields, such as brain-inspired intelligence, quantum information, future networks, and deep-sea and aerospace exploration. In addition, engineering sciences plan and implement many major special projects and scientific research projects, which produce many major original scientific and technological achievements, give birth to many emerging future industries, and fundamentally tackle key technologies and "bottleneck" technologies. Only by taking engineering sciences as the basis and guide, vigorously developing original engineering technology, and ensuring that the key core technologies are independently controllable can Chinabreak away from the constraints of western countries, strengthen high-level science and technology, and truly become an engineering giant. This can help China move forward from a big country to a strong country. The coordinated development of natural sciences, engineering sciences, and manufacturing foundations supports the major national scientific and technological projects and the construction of a scientific and technological giant.

Generally, China has gradually laid the foundation of science and technology in different stages, from catching up and filling in the domestic gap to occupying a place in the world. In particular, since the 19th National Congress of the Communist Party of China, China has vigorously strengthened modern engineering and technological science research with multi-disciplinary integration, gave full play to the advantages of the new national system, and strongly supported strategic scientific plans and scientific projects with a long cycle, high risk, and great difficulty. The *Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China* (hereinafter referred to as the *Outline of the 14th Five-Year Plan and Vision 2035*) clearly proposes to strengthen the national strategic science and technology capabilities and "formulate and implement strategic scientific plans and scientific projects in the basic and core fields related to national security and overall development."

In 2021, China's investment in R&D reached 2.79 trillion yuan, a growth rate of 4 percentage points compared with that of the previous year, and the funding for basic research was increased by 15.6%① compared with that in 2020. In particular, new breakthroughs have been made in many original and innovative fields, such as space exploration, nuclear physics, quantum science, and bioengineering. However, there is still a significant gap between China and the United States in the scientific and technological level. Specifically, original innovation is deficient; almost all high-end devices and equipment depend on imports, and core software, key devices, and basic materials are imported from other countries, which seriously threatens national security and economic development. More importantly, China lacks cutting-edge technology or subversive technological innovation and has not developed the scientific and technological ability to lead the future. The existing science and technology plan has not yet solved the problem of the relative separation of basic research and applied research, which is mainly reflected in three aspects.

(1) There is a lack of top-level design and planning for major national needs at the strategic level. The layout of basic research focuses on natural sciences and cross sciences, but the layout of engineering sciences is relatively weak. The bottom-up special establishment mode of "starting after mature development" can easily cause the "stack" and "barrel effect." The national strategic planning and resource allocation system and mechanism in science and technology should be improved urgently. The top-level design of the innovation-driven development strategy and the road map and timetable of major tasks should be further formulated and clarified.

(2) At the implementation level, linking up the application and the basic frontiers are applied and demonstrated in a short time for objective quick success and instant benefits, and the support for basic research is weakened; long-term continuous research on basic scientific problems and key and subversive technologies is insufficient, and the foundations are weak. The problems include the insufficient financial investment in basic research, the to-be-optimized expenditure structure, the inadequate preferential policies for basic research, the lack of multi-channel investment such as social donation and fund mechanisms, and the discontinuous and unstable investment mechanism supporting basic research.

(3) The problem-oriented approach should be enhanced in tackling key scientific and technological problems. Science and technology are unable to support emergencies in the most urgent research fields, such as national development strategy and improving people's living standards. Today, the world economy encounters a downturn, and the COVID-19 is exerting a profound effect. In an increasingly complex international environment, further breakthroughs in core technologies should be made in China, such as oil and natural gas, basic raw materials, high-end chips, industrial software, crop seeds, scientific test equipment, and chemical reagents.

Meanwhile, higher requirements are proposed for China to vigorously develop engineering sciences and serve the comprehensive construction of a modern socialist country in all respects in the process of industrialization, marketization, informatization, socialization, and ecology. The interdisciplinary and comprehensive characteristics of engineering sciences require that we should pay attention to and support disciplines in relevant fields to make engineering sciences more adaptable to the development of the times and more in line with the basic national conditions of the primary stage of socialism of China; we should establish the engineering concept of the new era and implement the new development philosophy emphasizing innovative, coordinated, green, and open development; we should combine the disciplines such as philosophy, humanities, and sociology to comprehensively consider and evaluate engineering activities. In this way, important ideological and theoretical guidance can be provided for us to effectively avoid relevant social problems in engineering activities.

3 International experience in the development plan of engineering sciences

In view of national or regional conditions and actual needs, major countries and regions in the world have focused on the preliminary exploration and research on new engineering technologies and new products (i.e., research before competition). They have formulated and implemented a series of strategic plans related to engineering sciences and included them in the national overall scientific and technological development strategic plan.

According to the strategic plans for development in engineering sciences successively released by the United States, the EU, the UK, Russia, Japan, and other major countries and

① National Bureau of Statistics. The ratio of R & D funds in 2021 to GDP of 2.79 trillion is 2.44% (2022-01-26)[2022-03-03]. http://www.stats.gov.cn/xxgk/sjfb/zxfb2020/202201/t20220126_1827037.html.

regions in the world (Table 1), we can learn that some plans are jointly formulated by many countries; for example, the *European Strategy Forum on Research Infrastructures Roadmap 2018* was formulated by more than 20 countries, including the UK, Germany, France, the Netherlands, Sweden, Denmark, and the Czech Republic. Other plans are released by specific functional departments, such as the *Department of Defense Technology Vision for an Era of Competition* issued by the Department of Defense of the United States and the *S&T Artificial Intelligence & Machine Learning Strategic Plan* issued by the Department of Homeland Security of the United States. Generally, the plans basically involve the most cutting-edge and emerging technologies and directions of engineering sciences and play an important role in promoting the global leading position of major countries and regions.

Table 1 Strategic planning plans in engineering sciences recently released by major countries

Country (region)	Release time	Name of strategic plan
The United States	2022	Technologies for American Innovation and National Security
	2022	Department of Defense Technology Vision for an Era of Competition
	2021	DoD AI and Data Acceleration (ADA) initiative
	2021	S&T Artificial Intelligence & Machine Learning Strategic Plan
	2020	Defense Space Strategy Summary
	2020	Sharpening America's Innovative Edge
	2018	National Space Strategy
	2018	National Space Policy
	2018	A National Machine Intelligence Strategy for the United States
	2018	Strategy For American Leadership in Advanced Manufacturing
	2018	Department of Defense Digital Engineering Strategy
	2015	A Strategy for American Innovation
	2015	Defense 2045: Assessing the Future Security Environment and Implications for Defense Policymakers
	2013	"BRAIN Initiative"
	2011	"Materials Genome Initiative"
European Union	2021	Coordinated Plan on Artificial Intelligence 2021 Review
	2020	A New Industrial Strategy for Europe
	2018	European Strategy Forum on Research Infrastructures Roadmap 2018
	2016	Space Strategy for Europe
	2014	Horizon 2020
Germany	2013	Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0
Britain	2022	Defence Space Strategy: Operationalising the Space Domain
	2021	National AI Strategy
Russia	2020	Strategy for Developing the Russian Arctic Zone and Ensuring National Security through 2035
	2019	Science and Technology Development Strategy of the Era Military Innovation Technopolis
	2016	Russian Federal Space Program for 2016–2025
Japan	2021	Semiconductor Digital Industry Strategy
	2018	The Fourth Mid-to-long-term Plan of Japan

Particularly, the Biden administration of the United States has significantly increased investment in basic research in view of the competition between China and the United States. The United States House of Representatives has proposed the *National Science Foundation for the Future Act*. It suggested that funds will be remarkably increased, and a new department of "Science and Engineering Solutions" will be established to strengthen the cross integration of natural sciences and engineering sciences and make the National Science Foundation solve practical social problems. This is also a typical example of the strategic initiative of the United States to develop engineering sciences.

Practice shows that these countries and regions have formulated development strategic plans at the national level, which has provided important funding and support for the development of national (regional) engineering sciences. The contents of these plans have four characteristics.

(1) The formulation and implementation of the strategic plan for the development of engineering sciences adopt a systematic and whole-chain management mode. Relevant institutions responsible for planning and roadmap formulation in various countries (regions) are also responsible for the coordination or management of engineering sciences, so as to reduce unnecessary links in the process of relevant plans from formulation to implementation. In this way, the relevant national key engineering and scientific projects can be supervised and managed by the institutions for the whole project process. In other words, after being included in the roadmap, such a project should be approved, funded, designed, constructed, and operated before its termination. Meanwhile, these institutions often establish mechanisms for the monitoring, evaluation, and regular updates of the development plans in engineering sciences to ensure the scientific effectiveness of their formulation and implementation.

(2) The formulation and implementation of the strategic plan for the development of engineering sciences is continuous on a long-term basis. Considering the actual national conditions of various countries, the layout of national advantageous fields shall be attended to, and the priority development directions of engineering sciences shall be formulated on the basis of the current national scientific and technological strength, scientific research background, government vision, and complex situations and challenges both at home and abroad. In the process of implementation, long-term and stable support shall be given to the priority development directions.

(3) The formulation of strategic plans for the development of engineering sciences strengthens the consultation mode of expert participation. While formulating these plans, countries (regions) should involve a wide range of stakeholders in decision-making, management, monitoring, and evaluation, invite experts from different institutions and fields to participate, absorb and adopt the views of relevant parties in various fields and disciplines. In this way, the plans can better consider the interests of all parties, and the implementation and operation are more scientific and reasonable.

(4) The formulation of strategic plans for the development of engineering sciences is scientific, and it also considers risks. When relevant institutions or departments of various countries (regions) screen and select engineering plans, they will first ponder whether the selected plans can achieve major scientific and technological breakthroughs and solve practical

problems. Then, they will consider the economic benefits and technical risks.

4 Suggestions and thoughts

It is required in the *Outline of the 14th Five-Year Plan and Vision 2035* that we should accelerate the construction of a global giant in science and technology, strengthen the national strategic scientific and technological strength, and comprehensively shape the new advantages of development. In view of the outstanding problems in the development of engineering sciences in China, three suggestions are put forward in this paper from the perspective of macro policy and development strategy.

(1) Engineering sciences should be incorporated into the *Ten-Year Plan for Basic Research*, and natural sciences and engineering sciences should be integrated for development, which organically forms China's strategic basic research system. In 2021, General Secretary Xi Jinping pointed out at the 20th Academician Meeting of CAS, the 15th Academician Meeting of CAE, and the 10th National Representatives Meeting of China Association for Science and Technology that "modern engineering and technological science is an indispensable bridge between scientific principles, industrial development, and engineering research and plays a key role in the system of modern science and technology." In the *Ten-Year Plan for Basic Research*, support for engineering sciences shall be increased, and the problem-oriented approach shall be strengthened; engineering science projects shall be deployed in response to national strategic needs and major global challenges; the organic integration, coordinated development, and mutual support of natural sciences and engineering sciences shall be promoted to generate original innovation and disruptive technologies; the problem that high-end scientific instruments, engineering machine tools, and industrial software are imported should be solved; enterprises should be encouraged to conduct whole chain scientific and technological innovation activities such as basic research of engineering sciences, technological innovation, achievement transformation, and industrialization to consolidate the main position of enterprise innovation.

(2) The layout of engineering sciences related to national science and technology security should be considered first to support the construction of China into a scientific and technological giant under the guidance of major national science and technology projects. Engineering strength is the backbone and cornerstone of a country and the "multiplier" to promote economic growth. Engineering sciences directly support the national economy and national defense construction and are the basis for building a great modern socialist country in all respects. Guided by the national major science and technology projects, the key areas related to national science and technology security and overall development should be the focus, and the investment in engineering science and technology should be increased. "Brave steps into the unmanned zones" or even "discovering unmanned zones" should be encouraged to provide a solid theoretical basis for cultivating original innovation and emerging industries. We should lead the development of high-end science and technology rather than follow behind others by taking cross-generational and track-changing ways to contribute to the transformation of China from a big country to a great country.

(3) In the implementation of major science and technology projects, in view of the basic problems, natural science and engineering scientific research should be planned, and a long-term stable and rolling development support mechanism should be established. The major science and technology projects of China will face the challenge of "unmanned zones" in the future, and a series of basic problems should be solved without international successful experience. The advantages of the new national system should be given full play to lay out natural science and engineering scientific research around the implementation of major science and technology projects and organize the strengths of China to work together to solve the key problems; a long-term stable and rolling development support mechanism should be established to achieve staged major scientific and technological achievements, and the project approval procedures should be simplified to provide continuous support directly.

(4) The opening-up efforts shall be strengthened in implementing major science and technology projects, and global science and technology resources shall be gathered to enhance China's international influence. Facing the global common challenges, such as deep space, viruses, and disasters, international major science and technology projects should be implemented to deepen global cooperation. Basic scientific issues should be concluded from major science and technology projects and released to the world. Scientists from all over the world should be invited to participate in research to strengthen the opening-up and cooperation and enhance China's international influence.

Acknowledgements

Sincere gratitudes go to academicians and experts Han Jiecai, Luo Jianbin, Wang Chi, Wang Wei, Sun Changpu, Jiang Song, Deng Xiaogang, Yang Yuanxi, Liu Ming, Wang Huaimin, Wu Zhaohui, Zhou Zhicheng, Hou Xiao, Lu Jun, Yang Xiaoniu, Bao Xinhe, Chen Hong, Meng Songhe, He Yongyong, Fan Quanlin, Bai Qingjiang, Wang Xuefeng, Fu Libin, Wang Xin, Wang Pei, Lou Liangsheng, Li Ling, Wu Junjie, Weng Shenjun, Zhong Xiaoqing, Dong Xiaolin, Anda, Xu Shouren, and Zheng Shilian for providing us with guidance and valuable suggestions.

References

1 Xi J P. Make China a Global Center for Science and Innovation. Qiushi, 2021, (6): 4–11 (in Chinese).

2 Kuang G L, Wang W Q. Management proposals focusing on the development issues of the large scientific facility project in our country. Science and Society, 2021, 11 (1): 1–11 (in Chinese).

3 Price D J D. Little Science, Big Science. New York: Columbia University Press, 1963.

4 Tao Y C, Hu Y S. Discussed American science in the perspectives of

relationship between little and big science. Studies in Science of Science, 2012, 30 (5): 660–666 (in Chinese).
5 Liu S. Great science&little science. Scientific and Technological Information, 2005, (1): 32 (in Chinese).
6 Pu M M. Big science and little science. World Science, 2005, (1): 4–6 (in Chinese).
7 Party Literature Research Office of the CPC Central Committee. Excerpts from Xi Jinping's Remarks on Scientific Innovation. Beijing: Central Literature Publishing House, 2016: 62 (in Chinese).
8 Sun H Y. Modern engineering and technical science drive the development of new discoveries and applications in basic science. China Scitechnology Think Tank, 2022, (1): 23–27 (in Chinese).
9 Zhang P F, Li H T. How it to be: A scientific institutionalized research based on engineers. Journal of Dialectics of Nature, 2021, 43 (7): 85–91 (in Chinese).
10 LüC D. Return in the Future: Qian Xuesen's Years of Seeking Knowledge. Hangzhou: Zhejiang Science and Technology Press, 2019: 277 (in Chinese).
11 Qian X S. Technological science. Chinese Science Bulletin, 1957, 2 (3): 97–104 (in Chinese).
12 Qian X S. Methodological issues in technological science. Journal of Dialectics of Nature, 1957, (1): 33–34 (in Chinese).
13 Qian X S. Engineering and engineering sciences. Advances in mechanics, 2009, 39 (6): 643–649 (in Chinese).
14 Li B C. Object, Contents and significance of engineering sciences: Analysis and thinking from perspective of philosophy of engineering. Journal of Engineering Studies, 2020, 12 (5): 463–471 (in Chinese).

Associate Professor LI Peinan with the Institutes of Science and Development of the Chinese Academy of Sciences (CAS) is mainly engaged in research on the consulting system of S&T policy-making and S&T think tanks. She has chaired and undertaken important national funded programs such as major consulting projects supported by CAS and the Chinese Academy of Engineering (CAE), National High-End Think Tank Council, Special Program of Ministry of Science and Technology, Office of the Central Cyberspace Affairs Commission, and Emergency Program of the National Natural Science Foundation of China (NSFC). In addition, she has published many academic papers in core journals from China and other countries. E-mail: lipeinan@casisd.cn

BAO Weimin, academician of CAS and the International Academy of Astronautics. He is currently director of the Science and Technology Commission of China Aerospace Science and Technology Corporation, vice chairman of the 10th Chinese Association for Science and Technology, member of the 11th, 12th, and 13th National Committee of the Chinese People's Political Consultative Conference (CPPCC), member of the Presidium of CAS, a trustee of the Engineering Sciences Section of the International Academy of Astronautics, and president of Chinese Society of Inertial Technology. He has been engaged in research on system design and control systems of spacecraft for a long time. He has participated in the development of the control system for multi-type spacecraft successively and has solved multiple technical problems for the development of spacecraft in China. He is the academic leader in the overall and control systems of Chinese spacecraft and one of the young and middle-aged experts with outstanding contributions to the defense-related science, technology, and industry in China. E-mail: baoweimin@cashq.ac.cn

