

# Establish a New Model for the Organization and Management of Major S&T Projects Based on Tailormade Policies<sup>1</sup>

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## Abstract

To foster self-reliance and self-improvement in science and technology (S&T) compatible with high-quality development, we should establish an organization and management model that conforms to the rules of scientific research, ensuring that the way organization methods evolve and reform is in line with the transformation and upgrading of the scientific and technological innovation paradigm. Against the backdrop of self-reliance and self-improvement in S&T, this paper systematically discusses the features of the reform of the organization and management model of major S&T projects in the world's largest economies and the associated new requirements. In addition, this paper analyzes the typical models of these projects and the future main trends in these countries. Furthermore, based on the actual situation of China's current development and the primary problems it faces, this paper explores a new model for organizing and managing major S&T projects and proposes corresponding reform measures.

**Keywords:** self-reliance and self-improvement in S&T, major S&T project, organization and management model

## Introduction

Major science and technology (S&T) projects and programs are vital parts of China's ambition of becoming an S&T world power and implementing an innovation-driven development strategy. The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China made it clear that we should "improve the way S&T projects are organized and managed". In the Three-Year (2021–2023) Blueprint Plan to Revamp the S&T System, it was also highlighted that we need to "reform and innovate the

way of launching and organizing major S&T projects, further enhancing the systematic competitiveness". Ushering in a new era, S&T management reform now faces new requirements and propositions—to establish a new system for organizing and managing S&T projects that not only conforms to the laws of S&T development, but also keeps in sync with the country's strategic needs. Under such circumstances, constructing a new management model for managing and organizing major S&T based on the self-reliance and self-improvement of S&T is of paramount significance and should be put high on the agenda.

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# 1. Theories and Research Background

## 1.1 The Connotation of Major S&T Projects and the Organization and Management Model

Academia does not yet have consensus on the definition or specific scope of a major S&T project. Domestically, Lan Jin-song and Xue Tian-xiang defined it as an expensive large-scale scientific and technological project of great significance that covers a wide range of content and entails long-term commitment to the national scientific research plan [1]. Chen Sheng-ping defined it as high-tech scientific research that is sought to expedite economic construction and solve the international frontier and major issues to achieve national strategic goals, with a profound impact on economic and social development, and in contention for a place in the international arena [2]. This paper argues that what major S&T projects intend to address are those strategic technologies that have a seminal influence on national security and economic and social development, a high threshold to make technological breakthroughs, and a long investment cycle requiring massive R&D investment and capital intensity, in which the government's efforts to coordinate their development and application are indispensable. The experience of various countries reveals that major S&T projects are often items listed in a country's S&T programs and are organizational units to implement these plans specifically. National S&T projects are a crucial means for the country to promote scientific research and resolve major S&T issues in economic and social development and national security. Therefore, the major S&T projects in this study include both civil and military fields. In the civil field, they mainly refer to the National S&T Major Projects.<sup>3,4</sup> The successful implementation of major S&T projects not only drives the leapfrog development of related disciplines, technologies, and industries, but also plays a key role in bolstering the country's innovation competence, comprehensive national strength, and international prestige. The organization and management model is an organic

combination of organizational structure and management mechanism based on which we can implement major S&T projects more efficiently.

## 1.2 New Features of the Organization and Management Model for Major S&T Projects

Major S&T projects often have basic characteristics such as reflecting the will of the government, integrating scientific and technological resources, high investment and risk, complex organization and management, and wide impact. Whereas in the new era, the organization and management model of major S&T projects based on the background of self-reliance and self-improvement in S&T should have the following new features.

First, it better reflects the will of the state. At present and for some time to come, the international environment that China faces will become even more intricate. Organizing and carrying out major S&T projects is not only related to China's position in international competition, but also determines whether China can successfully achieve self-reliance and self-improvement in S&T. The will of the state should be embedded in it more deeply, so as to make overall arrangements from the perspective of national interests and future strategies.

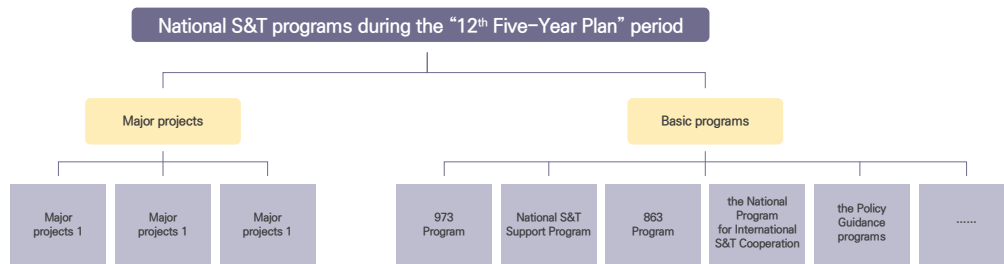
Second, various types of resources are further integrated. As this round of technological revolution progresses in depth, technological complexity increases and technological iteration accelerates, and breakthroughs in major technologies often depend more on the basic and holistic progress of national S&T, as well as the cross-fusion and comprehensive convergence of different disciplines and fields.

Third, market orientation is highlighted more. The traditional organization model for major S&T projects relies more on government investment. Given the projected huge demand for capital, chances are that the organization and management model relying on financial investment will no longer be

<sup>3</sup> Major national S&T projects aim to achieve national goals. Major strategic products, key common technologies, and major projects are completed within a certain time limit through breakthroughs in core technology and resource integration.

<sup>4</sup> Because the military domain involves secrets, this article discusses the project mainly in the civilian domain.

Figure 1 China's S&T programs during the 12th Five-Year Plan period



sustainable. There is an urgent need to increase the total investment of the whole society in technology through financial reform and innovation.

Fourth, it mirrors the efficiency of decision-making to a larger extent. In the new era, the task of reforming China's S&T system is even more pressing, while relevant resources are scarcer, which require us to adopt tailor-made policies, provide reasonable guidance, and boost the efficiency of organization and management decisions for major projects.

## 2. Main Developments and Issues in the Organization and Management Model of China's Major S&T Projects

### 2.1 Historical Evolution and Status Quo

The National Conference on Science held in 1978 marked the beginning of the implementation of various S&T programs and policies. The curtain of the reform of the S&T system was open, signaling that China's S&T industry entered a new historical stage. During the 12th Five-Year Plan period, the S&T programming system was further improved and gradually adjusted to a structure that consisted of major projects and basic programs, forming a thorough deployment for economic construction, the development of high tech and its industries, and serving as an engine for basic research. Major projects are earmarked programs with the purpose of achieving national strategic goals. Basic programs are the basic

form of the state's financial stability and continuous support for scientific and technological innovation activities, including the 973 Program (National Program on Key Basic Research Project of China), 863 Program (National High-Tech R&D Program of China), National S&T Support Program, the Policy Guidance programs, the National Program for International S&T Cooperation, and other programs (see Fig. 1)

At that time, the management framework, management system, and management activities of the different S&T programs in China were relatively independent, each with its own unique features and distinctive organization and management system. The organization and management system for major national S&T projects is divided into two levels: planning level and project level. Compared to the organization and management model of the 863 Program and the National S&T Support Program, major projects are different in the following aspects: First, in terms of the decision-making mechanism, major projects are under the unified leadership of the State Council, coordinated by the Leading Group for National S&T Education, and jointly managed by the Ministry of Science and Development (at the core), the National Development and Reform Commission (NDRC), and the Ministry of Finance. Second, in terms of management structure, major projects give more play to the role of the two systems of administrative management and technical management, enabling them to penetrate the whole process of project implementation. Third, in terms of the organization model, each major project is directly organized and managed with a well-defined life cycle. The project is launched upon maturity, and it is highly decentralized.

With the new technological revolution, industrial transformation, and rapid economic and social development, problems started to emerge in China's S&T programs and project management, revealing their incompatibilities with the trend of scientific and technological innovation and the Industrial Revolution. In 2014, the State Council issued the Notice on Issuing the Program for Deepening the Reform of the Administration of Central Finance Science and Technology Plans, in which it restructured the central financial S&T programming system. The adjusted national S&T programs include the National Natural Science Foundation of China, Major S&T Projects, Key R&D Programs, Technological Innovation Guidance Projects (Funds), and bases and talent projects (see Table 1). From the perspective of S&T management, establishing an open and unified national S&T management platform can address the problems of insufficient coordination and lack of top-level design. Restructuring the layout of S&T programs (such as programs and funds) can solve the problem of “fragmented” resource allocation.

Integrating resources to accomplish key tasks can solve the problem of the inadequate focus on scientific research projects. Establishing a new mechanism for professional institutions to manage specific projects can solve the problems in the transformation of government functions, achieving professional and scientific management.

## 2.2 Primary Issues in the Organization and Management of Major S&T Projects in China

Overall, with the advancement in the reform of the S&T system, China's S&T program management has changed radically. Meanwhile, in the volatile international and domestic environment, self-reliance and self-improvement in S&T have placed higher demands on the management of major S&T projects. In light of our investigation, it was discovered that the current organization and management of major national S&T projects in China encountered the following problems.

**Table 1** Changes in the Paradigm of China's National S&T Programs

Original S&T programs	Five new major S&T programs
National Natural Science Foundation of China	National Natural Science Foundation of China
Major national S&T projects	Major national S&T projects
973 Program, 863 Program, National S&T Support Program, and the National Program for International S&T Cooperation; industrial technology R&D funds managed by the NDRC and the Ministry of Industry and Information Technology; public welfare industrial research projects managed by 13 departments including the National Health and Family Planning Commission of the Ministry of Agriculture	National Key R&D Programs of China
Policy guidance projects and the National Fund for Technology Transfer and Commercialization managed by the Ministry of S&T; Emerging Industry Venture Capital Funds managed by the NDRC and the Ministry of Finance; SME development projects managed by four ministries (the part relating to S&T innovation)	Technological Innovation Guidance Project (Fund)
State Key Laboratories, National Engineering and Technology Research Centers, National S&T Infrastructure Platforms managed by the Ministry of S&T; National Engineering Laboratories managed by the NDRC, National Engineering Research Centers, etc.	Base and talent projects

Source: Collected by the research group

### **2.2.1 Selection of Topics: The Selected Topics Are Scattered, and the Selection Mechanism Is Defective**

First, the selected topics are scattered without a reasonable arrangement. According to relevant insiders, regarding the selection of topics, the goals are not unified, the arrangement is not justified, and the key objectives are not highlighted, resulting in insufficient investment in a single project. Second, the duration of selecting a project is too long, and the mechanism is not well designed. Some experts pointed out that the project selection link is too long, and the approval process often takes six months to one year, from project application to project launch, demonstrating that the project management efficiency is low.

### **2.2.2 Organization: Lack of Synergy and Disconnect between Academic Results and Commercialization**

First, the organization and management model is single, and there is a lack of synergy among undertaker units. Few understand the inherent laws governing major S&T projects, and the organization and management model is relatively single; there is a lack of synergy among the central government, local authorities, and departments, and coordination mechanisms still need to be improved. For some projects led by enterprises, there is a lack of cooperation between enterprises and universities, and in fact, universities play a negligible role in innovation. In addition, when multiple enterprises jointly undertake a project, the enterprises' own interests deviate from government goals, and so on. Second, the project establishment stage is underscored in project management, while little attention is paid to the later stages of industrialization. Some experts said that the management of major S&T projects has problems such as "value establishment and management, rather than project acceptance and transformation" and the lack of a transformation-oriented evaluation mechanism for scientific and technological achievements. In addition, the relevant supporting policies still need to be refined and implemented, and the conversion rate of academic results is low.

### **2.2.3 Funds: Unscientific Management of Funds and Flawed Investment Guarantee Mechanism**

First, the management of funds is unscientific, and the absence of support facilities is quite common. Research has found that the compensation for relevant personnel is not enough, and the financial support is not stable; the budget management system is strictly implemented, causing a lack of flexibility; it often takes a lot of time before the researchers receive funding from the state, and the funding from local governments and enterprises is inadequate. Second, channels and mechanisms for diversified funding sources have not yet been formed. Currently, the main sources of funding for major S&T projects in China are government financial investment and the matching of undertaker units. More diversified investment mechanisms are needed to invite the input of social capital, thus building the corresponding financial guaranteed mechanisms.

### **2.2.4 Talent: Unscientific Evaluation of Talents and Immature Incentive Mechanism**

First, the selection and employment mechanism and evaluation mechanism are unscientific. In the selection and employment of people for major S&T projects and team selection, problems exist, including overstressing seniority, scanty interdisciplinary studies, short evaluation duration, and inequivalence between power and responsibility in organization and implementation. Second, the relevant incentive mechanisms are immature. Although China has now introduced Guidance on the Equity-Based Incentives in State-Owned S&T Enterprises and other related policies, according to the investigation, many project undertaker units complained that they still encountered many obstacles in implementation, and incentives for researchers are not effective.

### 3. Analysis of the Organization and Management Model of Major S&T Projects around the World, Experience and Insight

#### 3.1 Traditional Major S&T Project Organization and Management Model

An effective organization and management model guarantees the smooth implementation of major S&T programs. In major economies, with economic and social development, their organization and management models of major S&T projects are evolving and innovating all the way. We adopted two dimensions to divide the organization and management models of major S&T projects in the world.

##### 3.1.1 According to the Extent to Which the Government Participates in the Management

According to the degree of government participation in the organization and management model of major S&T projects, we can roughly divide this model into three categories.

First, the government-led type. The typical model mainly uses a “project-based” approach to push major S&T projects forward. The concept of project based refers to a scenario where the government organizes and divides a major S&T project into several subprojects, which are assigned to different research institutes or research teams. This is what America's National Nanotechnology Initiative adopted. This model, as the main form of S&T management, was applied in most major S&T projects in China. That aside, due to differences in the establishment of project-based systems between different countries, the implementation results also vary substantially [3].

Second, the “government+market” type. It can be broadly divided into two categories: one is a joint research model; the other is a public-private partnership (PPP) model. The “joint research mechanism” is led by the government to establish joint research institutions with enterprises as the main body to carry out R&D collaboratively. A typical case

is the VLSI program implemented in Japan. The joint research mechanism is particularly suitable for major S&T projects that require enormous efforts to make a breakthrough. The participant enterprises often possess certain scientific and technological strengths and are willing to conduct joint research, while the government can ensure the smooth implementation of projects through organizational mechanisms.

A “PPP” model refers to a long-term partnership between the public sector and the private sector through a formal agreement for the provision of public services. This model facilitates benefit sharing and risk sharing between the public and private sectors, and it is ideal for projects where investments and returns are equally significant. Currently, this model is widely applied to the public infrastructure projects of many countries. Recent years have seen its growing popularity in China, and many financial projects using this model have generated successful results.

Third is the market-led type. It uses the “corporate legal entity” organization method, where multiple enterprises storm a strategic pass on key technical issues and share investment risks and benefits through Groupement d'intérêt économique (meaning economic interest grouping) or the direct establishment of corporate legal entities. For example, the “Airbus” program organized jointly by countries such as France, Germany, Spain, and the United Kingdom, is a typical example of the program model. This management model is more suitable for the major S&T projects involving strategic goods in competitive fields, as it can rationally allocate internal resources.

##### 3.1.2 According to Which Stage the Government Participates in

According to the stage of the project when the government steps in, the organization model for major global S&T projects can be roughly divided into three categories:

The first is the dotted model (also known as “isolated island”). The government pools its efforts on supporting basic research and making technical breakthroughs, without considering the commercial application of technology. It is essentially a disconnected organizational model that creates a gulf



between researchers and industrialization [4]. Typical cases include America's atomic energy and radar programs.

The second is a linear mode (also known as “island with bridges”). Bennis and Biederman stated that innovation entities need to be placed on “islands” and protected from the influence of “bureaucrats”—too frequent bureaucratic pressure from large companies or institutions will suppress and destroy the innovation process. Nonetheless, they noted that there must also be a “bridge” connecting innovation activities—innovation teams must establish close links with top decision makers, who can drive innovation and provide the resources needed [5]. Typical cases include the DARPA model (Defense Advanced Research Projects Agency) in the United States. DARPA is a highly autonomous organizational island, but it also has close ties (bridges) with senior officials of the Pentagon, so that the new technologies can be transferred to the broader defense sector [6].

The third is the innovation ecosystem model: In comparison, countries such as Germany, Japan, Taiwan, South Korea, and other countries attach more importance to the layout of the entire industry chain during the implementation of major S&T projects, forming a broader innovation ecosystem organization. For example, Germany's High Technology Strategy 2025 covers all areas of the German federal government's research and innovation policy. During its implementation, Germany adopted a task-oriented approach to facilitate the participation of different actors from the intellectual community, the business community, and society.

### 3.2 New Trends in the Dynamics of Typical Countries

#### 3.2.1 America: A New Organization and Management Entity Was Established for S&T Projects in Attempts to Bridge the Whole Process from Technology R&D to Industrialization

In January 2021, the U.S. President's Council of Advisors on Science and Technology (PCAST) submitted to the government a report titled “Industries of The Future Institutes: A New Model for American Science and Technology Leadership”, officially proposing the concept and design framework for the Industries of The Future Institutes (IoTFIS) [7]. IoTFIS is a new innovation entity designed by the United States to implement future industrial development strategies. It is formed in response to national strategic needs, featuring multidepartmental participation, public-private co-construction, diversified investment, and market-based operation. Its organizational model and management mechanism are unique. What sets IoTFIS apart is that it involves all the public and private sectors in industrial innovation as core partners, meanwhile spanning the entire innovation chain from basic research and applied research to the industrialization of new technologies.<sup>5</sup>

#### 3.2.2 Germany: Proposed that the Organization and Management of S&T Projects Be Oriented Toward the Future Innovation Chain

In April 2021, the German Federal Ministry of Education and Research (BMBF) released a report titled “Research for Technological Sovereignty”, [8] which discussed the importance of technological sovereignty and analyzed measures to consolidate and supplement Germany's technological competitiveness

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<sup>5</sup> PCAST pointed out that two major structural problems within the U.S. research system have taken a toll on the efficiency and vitality of future industrial technological innovation. First, different departments and links in the innovation chain are fragmented. The U.S. National Laboratory has led a myriad of cutting-edge scientific research, but it shows weakness in converting research results into economies of scale, and the technology transfer process between the national laboratory and industry is long and full of obstacles. The high cost of trial and error for academic institutions such as universities for such a conversion has dampened the motivation of institutions. The industry sector often focuses only on applied research at the late stage, while lacking interest in front-end basic and pioneering research. Second, the administrative and supervisory burden in scientific research management is too heavy. Government-funded research often requires researchers to spend a lot of time on administrative work. The management model is no longer geared toward modern, agile, and fast-paced scientific research needs, which stifles the creativity of researchers.

and leadership in related fields from a future-oriented perspective. The report put forward that mastering technological sovereignty requires a holistic policy approach, which means that all stages of the innovation chain and all participants in the innovation process should proceed under a holistic view. Through the new BMBF program, The Future of Value Creation, Germany will invest in more specific areas to build the core of technological sovereignty, with an emphasis on R&D to strengthen advantages, understand and resolve global dependencies and restrictions, and provide German companies with a wide range of decision-making options.

### 3.3 Experience and Enlightenment

From the analysis of the dynamics of major countries in the world, we can gain insight from the following three aspects.

- (1) The organization and management of major S&T projects shall be in tune with the stage and characteristics of the project. The experience of the above international cases told us that there is no such fixed management model in the organizations that undertake major projects, but if any, the model should match the research stage and characteristics of the project in ways to achieve good results. The full life cycle of major projects should be analyzed, so as to determine the stage characteristics of major projects in scientific and technological research, technological development and industrialization, and so on. In this way, we can use a contingency theory to adjust the organization and management model according to the circumstances. For example, America's DARPA tends to concentrate large amounts of research funding on research centers. Over time, many research centers have developed into computer departments of some of the leading academic institutions in the U.S. In contrast, the NSF supports researchers in more diverse institutions, awards scholarships to graduate students, and funds research equipment and infrastructure. It can be assumed that every U.S. federal government agency has a different set of mechanisms to shore up research, and these mechanisms are all in line with the stages and characteristics of major S&T projects.
- (2) In global and strategic areas, a government-led System of Nationwide Mobilization can be adopted. In the competition between countries, in order to gain a strategic advantage, direct government investment or organizing and guiding enterprises and research institutes to invest jointly in major S&T projects has become the norm. Practices have proven that since S&T is the lynchpin of the national strategy, organizing major S&T programs at the national level has nothing to do with the market or ideology, but is an inevitable choice that reflects the functions of the state [9]. The history of U.S. atomic energy research proves the importance of the government's centralized guidance and support for major S&T projects. Participants in the Manhattan Project have commented that, given the U.S. Congress's traditional restrictions on federal spending, the U.S. can never make any atomic bomb in peacetime.
- (3) In the future, more attention should be paid to market orientation and innovative ecological management. The future trends of the U.S. and Germany show that more and more countries are beginning to value full-chain and full-cycle management. Through America's exploration of IoTFIS, we can find that the country is urgently seeking to enhance its advanced industries and technology by optimizing the organizational model. Germany's high-technology strategy and technological sovereignty report also shows that government departments need to make important innovations in setting up and optimizing the organization of S&T projects. Furthermore, when drawing on the organization and management model of major international S&T projects, we should comprehensively consider China's national conditions to formulate policies correspondingly. From the international experience of major S&T programs relating to the promotion of industrial development, it can be seen that the government has taken the lead in the direction of the plan, but enterprises are the main actors in the implementation of the plans. The formation of this pattern is closely related to the R&D capabilities of foreign companies themselves. Currently, with the exception of a few industries, most industries



in China do not have such enterprises with potent scientific and research capabilities. Therefore, as we learn from the organization and management model of major international S&T projects, we should also be aware of our actual situation and formulate tailor-made policies.

## 4. Exploring and Constructing a New Model of Organization and Management of Major S&T Projects

As the situation at home and abroad changes, in the context of self-reliance and self-improvement in S&T, factors such as technical conditions, nature of demand, and the industrial conditions in the R&D of major S&T projects have all changed drastically, and the corresponding organizational models need to be adjusted urgently. Judging from the state of management and development of major S&T projects in China, as well as the trends and experiences in international dynamics, we should implement tailor-made policies in the project organization according to the characteristics of the project and which stage it is in, so as to achieve delicacy management.

### 4.1 Tailor-made Policies: Classify According to Project Characteristics

Major S&T programs have different goals and characteristics and are in different stages of technological development, which directly lead to differences in organization and management models. Therefore, when discussing how to reform the management model of major S&T projects, we should first classify the projects properly according to their characteristics. However, the academic circle is still working on clarifying the classification of major projects and there is no final conclusion. Among them, some representative viewpoints, such as those of Feng Shen-hong, held that based on the forms of the target results, these projects can be divided into four categories: scientific data type,<sup>6</sup> key technology type,<sup>7</sup> strategic product type,<sup>8</sup> and major engineering (system) type.<sup>9</sup> According to the stages of technological development, these projects can be divided into three categories: scientific exploration type,<sup>10</sup> breakthrough-seeking S&T type,<sup>11</sup> and technology development type<sup>12</sup> [3]. According to Fang Han-ting, these projects can be divided into three categories: major scientific and technological infrastructure, major strategic products,<sup>13</sup> and strategic industries.<sup>14</sup> Lei Jia-su, on the other hand, argued that these projects can be divided into two categories: consolidation of the foundation and major needs, while the types of major needs can

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<sup>6</sup> Through large-scale or even global scientific research or testing activities, scientific data are systematically collected and collated to provide a foundation for breakthroughs in major scientific issues and targeted technological development.

<sup>7</sup> A major science and technology program set up to master and make breakthroughs in core technologies for the implementation of major products and projects and common technologies that block industrial development.

<sup>8</sup> A major science and technology program set up for strategic industries related to the lifeline of the country, such as large aircraft and manned space, and national defense and security.

<sup>9</sup> A major science and technology program set up for projects that contain a large number of scientific and technological problems, and those with a strong engineering construction nature, and complex systems with highly integrated systems.

<sup>10</sup> A major science and technology program that focuses on the acquisition and analysis of basic scientific data and making breakthroughs in major scientific issues, and will not generate huge economic and social benefits in the short term.

<sup>11</sup> A major science and technology program that requires breakthroughs in both basic theory and technology for strategic core common technologies that restrict industrial development, or strategic products and key technologies in major projects.

<sup>12</sup> A major science and technology program that aims to solve some bottleneck technologies and common technical problems in the development of enterprises or industries, although these problems have no theoretical bottlenecks, and have a positive effect on the development of enterprise and industrial science and technology.

<sup>13</sup> For example, Two Bombs, One Satellite, manned space, are strategic products. This type of product does not need to be marketed as long as the scale can meet the usage requirement.

<sup>14</sup> It can considerably enhance the future competitiveness of the entire country and can be industrialized.

also be further divided into four categories according to different fields—national defense, industry, society, and people's livelihood. This study intends to use three dimensions for classification: technology development stages, result types, and main users.

First, according to the technology development stages, these projects can be divided into two categories: one is frontier technology R&D, and the other is breakthrough-seeking mature technology research. The roles that the government and the market play vary in the two types.

(1) Frontier technology: It mainly refers to forward-looking, leading, and exploratory major technologies in the high-tech field. It is an essential bedrock for future high-tech upgrading and underpins the development of emerging industries, as well as an indicator that comprehensively embodies the country's high-tech innovation capabilities. It is mainly represented by fields such as artificial intelligence, quantum computing, and biotechnology. Frontier technologies are not further classified because the market prospects are unclear and the technology is not yet mature, which makes it hard to judge the main users and types of results.

(2) Breakthrough-seeking mature technology research: It mainly refers to strategically core common technologies that constrain industrial development, or key technologies in strategic products and major projects. These technologies themselves have entered a mature stage but require breakthroughs in basic theory or technology. For mature technology, its stage requires us, in addition to solving technical problems, to reinforce industrial competitiveness after making technological breakthroughs, implying that the government and the market are equally important.

Breakthrough-seeking mature technology research has two key element dimensions. From the perspective of global practice, for mature technology, the demand side (main users) is often the key factor that determines

whether the technology can be industrialized successfully. The reason mainly lies in the different sensitivity levels of users to product requirements such as reliability, stability, and accuracy, so the profit margins will vary. Thus, according to the types of main users, it can be divided into two categories: government users and market users. When the main users are the government, such as national defense and security, or the products have obvious public attributes,<sup>15</sup> the industrialization of major S&T projects is relatively easy to succeed<sup>16</sup>; when the main users are enterprises, consumers, and so on, the industrialization is often more difficult.<sup>17</sup> On the other hand, the complexity of the results is also a major factor in classifying the outcome type. According to the types of results, it can be divided into strategic products and strategic industries. Strategic products mainly refer to special categories of products such as defense and military industry, or parts and intermediates containing key core technologies. Strategic industries mainly refer to highly integrated complex systems with the ability to generate large-scale industrialized results. Hence, four types of major S&T projects are identified below.

(1) Major strategic products (government as the main user): It mainly refers to strategic products that are vital to the survival of the country and national defense and security, such as Two Bombs, One Satellite, manned space, and the BeiDou Navigation Satellite System. This type of product often has clearly identified goals. With the government as the customer, it does not need large-scale marketization, as long as it can meet safety performance indicators and reach a certain scale.

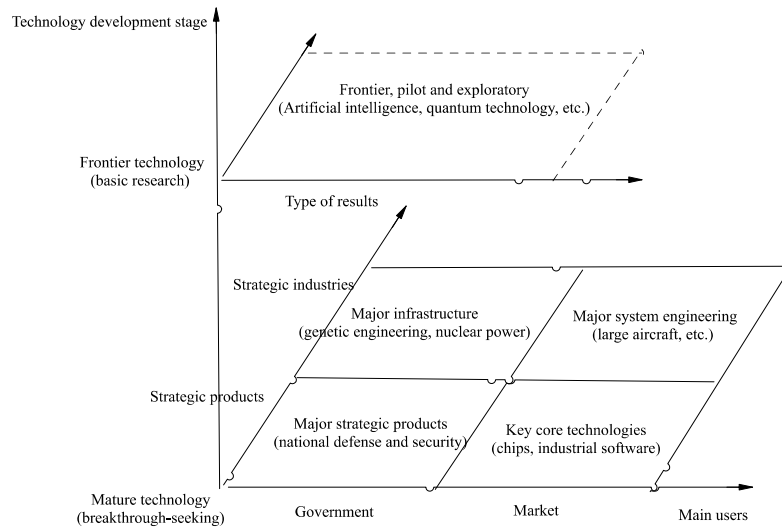
(2) Major infrastructure (government as the main user): It usually refers to large-scale or even global scientific research or basic scientific activities, as well as major infrastructure that props up breakthroughs in major scientific issues and technological development, such as the Human Genome Project.

<sup>15</sup> The government is often the buyer, as such projects involve national security, large project investment, and profit spillover.

<sup>16</sup> Since the government market is characterized by buyer monopoly, low degree of competition, insensitivity to product price and quality, and single demand.

<sup>17</sup> Because of its high degree of competition, diversified customer needs, high price, and quality sensitivity.

Figure 2 Main types of major S&T projects



(3) Key core technology (market as the main user):

It usually refers to core technologies (parts, intermediates) implemented to master and make breakthroughs in major strategic products and projects, and common technologies that constrain industrial development. This type of technological progress often depends on how the basic principles are mastered and advanced. To make a breakthrough, technological research is more basic and convergent and requires strengthened basic research and interdisciplinary joint efforts represented by chips, high-end CNC machine tools, and so on.

(4) Major system engineering (market as the main user): It usually refers to projects teeming with numerous unsolved scientific and technological problems and a strong engineering construction nature, and complex systems that are highly integrated. In summary, we classified the key core technologies of major S&T projects into five typical types (Fig. 2).

#### 4.2 Tailormade Policies: Exploring Adaptive Organization and Management Models

Based on the characteristics of the project itself, referring to international experience, it is proposed that we should establish different organizations and

management according to the characteristics of various projects.

(1) Frontier technology: The R&D of frontier technology is in its early stages. It often features high uncertainty and rapid technology iteration. In the early exploratory research stage, uncertainty and risk are high, and market failures can happen, making it hard to bring this type of technology into full play. The government functions as a supporter of early basic research and applied basic research. The organizational model for the basic research stage of such major projects can be led by the government, relying on national strategic scientific and technological forces such as national laboratories, universities, scientific research institutes, and so on to take the lead in organizing project implementation, and conduct research through methods such as “project based”, “joint research”, and “island with bridge model”.

(2) Major strategic products: Major technologies in a few key fields represented by Two Bombs, One Satellite, and national defense and security technology. For most of these projects, the technology has reached maturity, and market failure happens due to technology sensitivity and a limited number of users. International experience shows that the traditional System of Nationwide Mobilization can achieve prominent

effects in narrowing the technology gap. In terms of the project organization model, the government should take the lead and adopt the System of Nationwide Mobilization and a project-based approach, or a “dotted model” to concentrate on making breakthroughs.

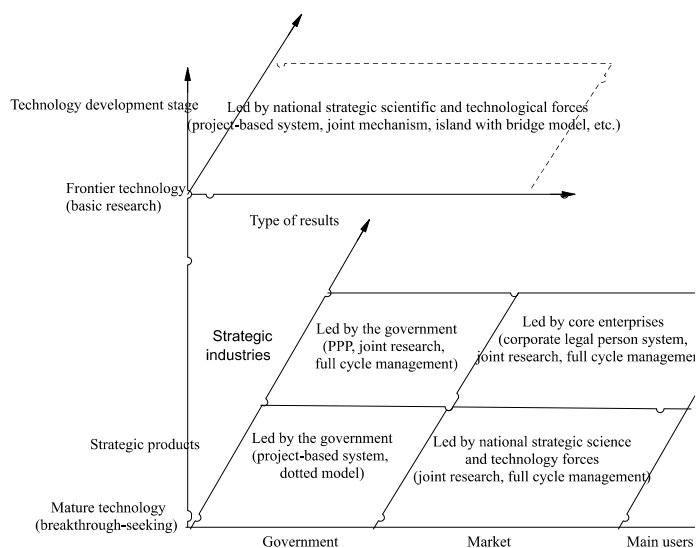
- (3) Major infrastructure: These major S&T projects are associated with the public, large capital investment, high integration complexity, and are often led by the government. In terms of the organizational model, the government should take the lead, adopt a “joint research” approach and collaborate with enterprises, and universities, or leverage the method of PPP to organize, or innovate the management of ecological organizations.
- (4) Key core technology: R&D of key core technologies can rely on national strategic scientific and technological forces such as national laboratories, universities, and research institutes to take the lead in organizing project implementation. Since the diversity of participants determines the diversification of goals, inputs, and interests in the implementation process, it is often difficult to

coordinate the organization. Therefore, the key to the success of such projects is to form a concise and clear technology roadmap, and establish reasonable investment and benefit distribution mechanisms and vigorous organizational coordination mechanisms.

- (5) Major system engineering: Market-oriented major system projects are often costly, have stringent plans, extremely high requirements for quality, and require strict process management. We can adopt an enterprise-led (joint-led) research model to establish a joint research mechanism among enterprises, universities, research institutes, and end users, as well as upstream and downstream enterprises. In terms of the project organization model, the enterprise legal person system and innovative ecological management model are optional.

Given the characteristics of technological development and the adaptability of organizational models, we should adopt different organization and management models for major S&T projects whose characteristics differ (as shown in Fig. 3).

**Figure 3** The corresponding relationship between major S&T project types and the organization and management models



### 4.3 Policy Proposals for Taking Major Initiatives to Support the Reform

**In General:** we should take a problem-oriented approach, bearing in mind the country's urgent needs and long-term development, and establish a demand-oriented and problem-oriented project formation mechanism; combine the government with the market, bolster the position of enterprises as an innovation entity, and invigorate market players; adopt tailor-made policies, building a new model that blends the management chain and innovation chain according to the type of project and which stage it is in; keep reforming and innovating, treating innovation and reform as a vent for making breakthroughs, and carry out systematic reforms in project formulation, organizational decision-making, selection and employment mechanisms, capital investment methods, and performance evaluation orientation in line with the organizational and implementation characteristics of major projects, so as to eradicate institutional and systematic barriers.

**First, strengthen top-level design and optimize organization and decision-making mechanisms.** Give full play to the role of the state as the organizer of major S&T projects and the coordinator of all kinds of major S&T projects. Adopt tailor-made policies and innovate project organization models according to the characteristics of major S&T projects. The leading unit should be entities and set apart a dedicated team to be held responsible, in which flat management should be adopted. Establish sound working mechanisms, optimize organizational decision-making mechanisms, and perfect top-level design for major tasks.

**Second, focus on some major S&T projects and coordinate national strategic resources.** Adhere to the principles of strategy, the overall situation and criticality, select a few major strategic products or major projects that reflect the will of the state, have clear goals and feasible plans, and require the pooling of resources, and organize cross-sectoral and multidepartmental corps to collaborate on key strategic products or major projects, giving full play to the advantage of a new System of Nationwide Mobilization.

**Third, explore and implement a new employment system and establish and improve talent incentive mechanisms.** Optimize the talent ecosystem suitable for major tasks and implement new employment mechanisms, such as the “appointing person in charge”, “tender system to reward those capable”, and “horse racing system” (an elimination mechanism through fair competition) according to the type of organization and management model. Establish a special compensation system for talents who make breakthroughs, improve the benefit-sharing mechanism, and implement special talent introduction policies such as the green channel. In frontier areas, we should give full play to the role of chief technical engineers and top scientists, and grant them the right to make decisions on routes, funding, and resource allocation.

**Fourth, reform the funding management system and drive the formation of a stable, sustained, and diversified investment mechanism.** We should improve the funding mechanism, step up central financial investment, and give priority to secure that major breakthrough-seeking tasks are adequately funded, achieving high coverage of financial funds. Strictly make sure that local financial resources are in place and enterprises are financed on their own to ensure that funds are available in a timely manner. Set up a stable, sustainable, diversified, and integrated long-term investment mechanism, and form a diversified investment mechanism led by the state and involving the participation of local governments and society.

**Fifth, optimize the ecosystem and improve the market mechanism of result verification, as well as product upgrading and iteration.** Formulate better government procurement policies, stress the main responsibilities of purchasers, and step up government procurement efforts to breakthrough-seeking products through measures such as priority procurement, initial purchase, and ordering. In addition, promote the first (set of) pilot insurance compensation for major technical equipment, build demonstration bases for industrialization of major tasks and achievements, and crack bottlenecks in the application of results, so that the results can be integrated comprehensively and transformed to be applied in our daily life.

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