

Project Review of Strategic Research on Disruptive Technologies in Engineering Science and Technology

General Plan Group of *Strategic Research on Disruptive Technologies in Engineering Science and Technology*

Abstract: Disruptive technologies have become an important driving force for economic and social development, as well as military reform. Strengthening disruptive technological innovation is particularly important for realizing the development, transformation, and future of strategic initiatives in China. Accordingly, the Chinese Academy of Engineering has established a major advisory project—Strategic Research on Disruptive Technologies in Engineering Science and Technology—with the aim to plan the development of disruptive technologies in engineering, science, and technology in China. This paper systematically introduces the research objectives, contents, and methods of this project, and it summarizes the progress in forecasting and identifying methods, tracking and providing early warning of worldwide disruptive technologies, and identifying and evaluating major disruptive technology directions. Further, this paper summarizes the outcomes and limitations of project implementation.

Keywords: 2035; engineering science and technology in China; disruptive technology; strategic research

1 Introduction

Disruptive technology was first proposed by Clayton Christensen, a professor at Harvard Business School. The term refers to a technology that has a disruptive effect on an application field or industry [1]. Disruptive technology is revolutionary, which leads to the reconstruction of systems and hierarchies of an application field. Therefore, it has become an important driving force for economic and social development, and for military transformation. Currently, China is in a critical period of national transition from being large to being competitive. The new rounds of scientific, technological, and industrial transformation have formed a historic convergence with the transformation of China's development. China is facing a rare historical opportunity, but there exist severe challenges such as being squeezed by strategic rivals and gap widening. Strengthening disruptive technological innovation is particularly important for China to realize the control of key core technologies, improve the quality of scientific and technological innovation to achieve leap-forward development, and to grasp the strategic initiatives of future development. In a report from the 19th CPC National Congress, it is clearly stated that China aims to strengthen disruptive technological innovation, provide strong support for building a technologically strong country, and develop disruptive technology to an unprecedented strategic level.

The Chinese Academy of Engineering (CAE) is keenly aware of the new era of disruptive technological revolution and the changes in the country's development. Based on major advisory projects such as *Strategic Research on Development of Engineering Science and Technology in China by 2035*, and *Prediction Research on Major Disruptive Technology Leading to Industrial Change*, in 2017, CAE launched a major strategic consulting project—*Strategic Research on Disruptive Technologies in Science and Engineering Technology*. This project aims to conduct continuous and systematic disruptive technology strategy research, with a view to gather academics and experts from home and abroad, and wisdom from all walks-of-life in China. Further, it will determine the development trends of disruptive technology, identify and select preferential and major disruptive technology directions, and study the law of disruptive technology development to provide advice and suggestions for the

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country. Eventually, the project is expected to promote the accelerated development of disruptive technology in China, contribute to the construction of a powerful nation of science and technology, and facilitate the long-term sustainable development of China's economy and society [2].

2 Research objectives, content, and requirements

2.1 Objectives

The *Strategic Research on Disruptive Technology in Science and Engineering Technology* project aims to plan the development of China's national disruptive technology for science and engineering technology. The project is expected to achieve the following objectives. First, it will develop a disruptive technology strategic research system, building channels and mechanisms for disruptive technology continuous data collection and information analysis. Second, it will analyze the global development trends of disruptive technologies, studying and judging the development direction and priorities while providing disruptive technological warnings to participants in major fields of China. Third, it will predict and identify major disruptive technological development directions, forming consultation committees to accelerate the research and development (R&D) of disruptive technologies in China, supporting national objectives and policy formulation. Fourth, it will deliver accurate and authoritative information to society as needed, promoting the rapid growth of China's disruptive technology and relevant applications.

2.2 Contents

The current project addresses the following aspects. First, it examines disruptive technological concepts and frameworks, including its concepts, connotations, and evolution. This allows gaining a global view of disruptive technologies. The second aspect involves continuously tracking global disruptive technology development while studying and judging development trends and priorities. Third, it identifies and evaluates past, present, and future applications of disruptive technologies, including identifying the current major disruptive technology directions and selecting the disruptive technologies that must be prioritized or accelerated in China based on national strategic needs and the world's technological, economic, military, and other competitive situations. Fourth, it involves studying disruptive technology development measures and policy proposals and promulgating suggestions on accelerating development based on the characteristics of disruptive technology, China's national conditions, and the status quo of related fields.

2.3 Requirements

The project is intended to study disruptive technology based on the consolidated research of science and engineering technology developments while providing consultation and advice for the country. With an emphasis on "national orientation and standpoint," the project will be handled with a strategic perspective, a global view, and a practical utility. There are five research requirements for this project. First, guided by strategic needs, it will focus on systematic and comprehensive research. Second, bound to the characteristics of disruptive technology, it will focus on the diversity and openness of research methods. Third, making full use of existing foundations, it will consider the connections and complementarity of related projects. Fourth, it will provide guidance to decision makers for appropriate advancements, oriented to Year 2035, by focusing on disruptive technologies that could be realized in the next 10 to 15 years. Fifth, it will summarize and publish results in a timely manner.

3 Research approach

By focusing on the objectives, fully considering the characteristics and current status of disruptive technology strategic research, and relying on the foundation of the strategic research of the CAE, this project will be conducted using the following approaches: it will attach equal importance to understanding and practice, entail an all-field involvement with matrix research, and provide an overall design with separate application and integration.

"Equal importance" refers to current research on disruptive technology being in its relative infancy. Hitherto, there is no unified understanding of disruptive technologies in academic circles or corresponding research method and tools. However, this project vigorously conducts basic research on disruptive technology to understand the concepts, significance, and evolution of such technologies, consolidates the cognitive basis of strategic research, and develops methods and tools for strategic research. The project will rely on the existing knowledge and research structure, which simultaneously collects, predicts, identifies, and evaluates disruptive technologies, while also promoting selected disruptive technological directions and encouraging various groups to explore appropriate research methods adapted to their respective fields according to their corresponding characteristics. The project will provide strategic research using a variety of paths and methods. Practical application and theoretical understanding shall interact synergistically, such that the understanding is deepened in practice, and practice is improved with the help of experience.

"All-field involvement with matrix research" refers to the integration of all fields, covering all areas of engineering technology, and achieving an all-field involvement. The research shall be practical, requiring a vertically deep and horizontally integrated research matrix research, i.e., it would perform vertical in-depth

research to produce tangible results and improve the feasibility of research, and it would synchronously conduct horizontal cross-field integrated research to enhance the systematic-ness and comprehensiveness. Thus, the project will rely on nine departments at CAE to set up a longitudinal research program covering the nine fields of engineering science and technology. The Chinese Academy of Engineering Innovation Strategy will provide the horizontal integration. Furthermore, to improve the completeness of the research chain, a basic research project is planned based on the team of academicians of the Chinese Academy of Sciences to form a “1 (red) + 9 (purple) + 1 (orange)” project frame (Fig. 1).

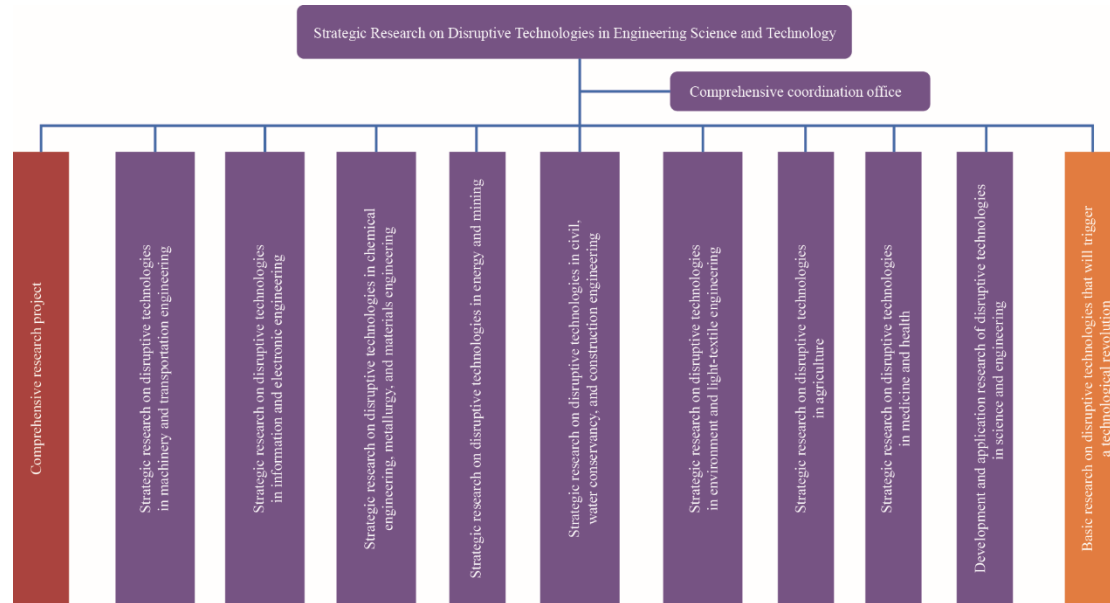


Fig. 1. Project frame.

The “overall design” refers to planning a step-by-step field-based implementation, and the final integration. Through this process, the project can be divided into three stages. First, there will be an overall planning stage combined with organic planning. The comprehensive team will integrate separate plans from various fields, emphasizing a homogeneous design while considering the characteristics and features of each field. Second, there will be a step-by-step and field-based implementation stage focusing on the combination of separated and overall actions. Focusing on each field’s research, the comprehensive team will provide cross-field and holistic research to strengthen deep research on priority while considering overall coverage. Third, there will be an integration stage, which will focus on deepening research and multi-dimensional evaluation, comprehensively integrating project research outputs while emphasizing its global and strategic nature.

4 Implementation

The overall framework of implementation, as described above, is presented in Fig. 2.

4.1 Concept and overall framework

In-depth research and systematic analysis of the concept and development of disruptive technologies will be conducted using various tools (e.g., knowledge graphs), the contexts of typical disruptive technology development will be sorted along with proposing preliminary frameworks based on key evolutionary factors. The team will then adaptively research a typical disruptive technology framework, gradually expanding it to other technology groups, field disruptive technologies, and overall strategies. The team will propose the overall framework of disruptive technology (Fig. 2) to provide a relevant global view, targeting single disruptive technology, and exposing the link between multiple technologies. The overall research framework focuses on comprehensive teams combined with field research groups. With the support of superior organizations in China, an open and collaborative research team will be built to systematically conduct research work.

4.2 Tracking research

This project focuses on four levels of development. First, it will evaluate the frontier of global disruptive technology development. Second, it will locate and describe strategies, plans, policies, and major projects from the international community. Third, it will access think tanks, universities, and venture-capital firms. Fourth, it will utilize world-renowned innovative companies. Using trend tracking, the project team will publish the *Disruptive Technology Express* newsletter on a monthly basis to promptly study and judge the development trends and priorities of global disruptive technologies, providing disruptive technological warnings to participants in major

fields of China, as well as the state, governing authorities, relevant academicians, and experts. The project includes tracking research on disruptive technology development with an open mind. On one hand, by fully utilizing the power of the project, a special intelligence team will be established to conduct fixed-point and continuous tracking of advanced national government agencies, major think tanks, and commercial entities. By utilizing the joint effort of technical experts in each field, relevant tracking research will accelerate; comprehensive research and technology exploration are regarded as equally important. On the other hand, private forces will be engaged by the project team, consolidating the wisdom of the masses, and conducting multi-channel and multi-dimensional tracking research on disruptive technologies. This effort will be a venture into the establishment of an open, diverse, and flexible information collection channel.

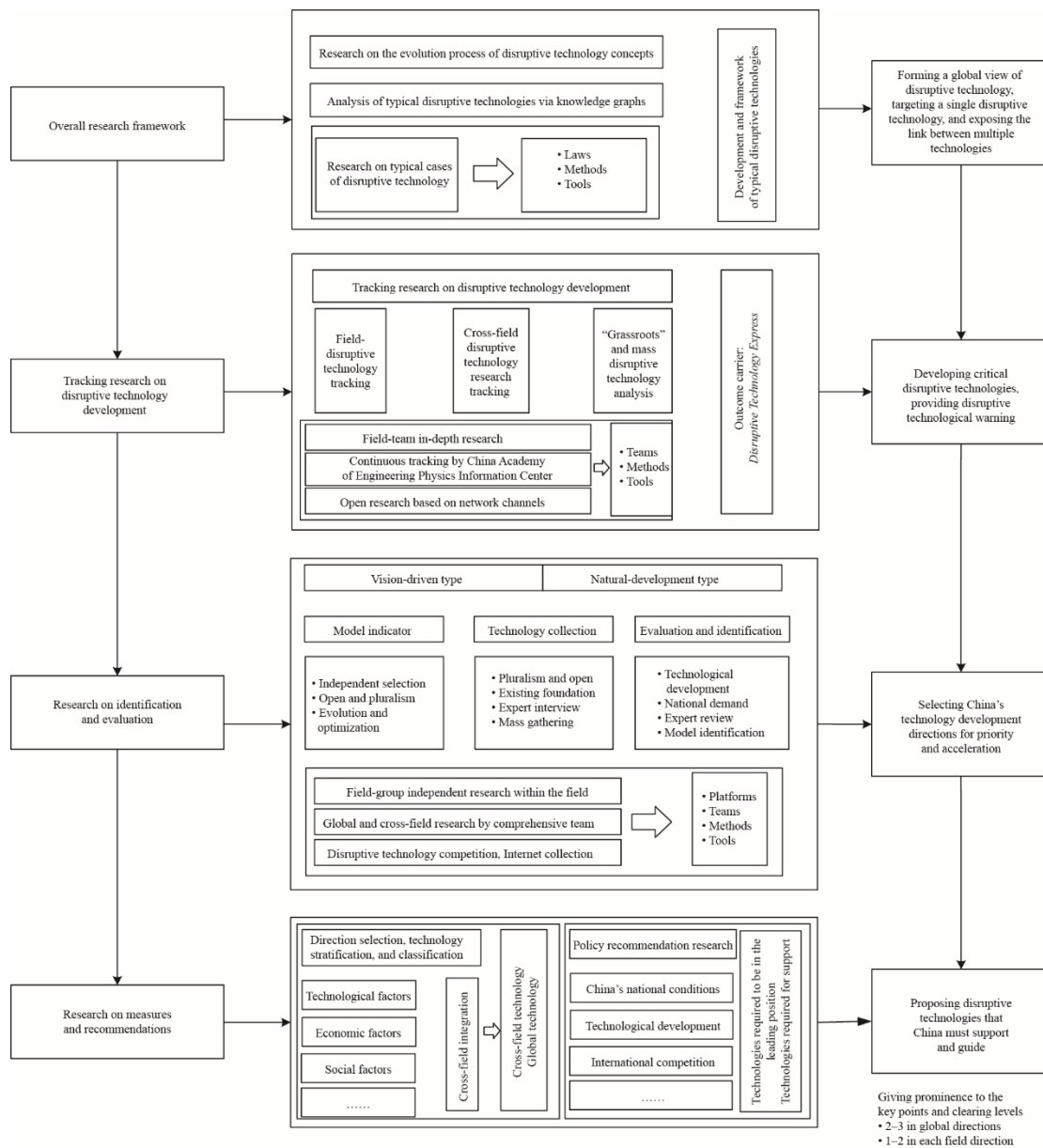


Fig. 2. Overall framework of project implementation.

4.3 Identification, evaluation, and research

Identifying, evaluating, and researching disruptive technologies depends on national strategic needs and the global development trends of science, technology, economy, and military. For this project, theoretical research and practical operations will be considered together. The engineering management team will manage research on disruptive technology identification and evaluation methods and tools to propose a relatively unified framework with corresponding methods for disruptive technology identification and evaluation. Using advanced methodologies, each field team will independently select the appropriate methodological tools and expert judgments. They will screen major disruptive technologies in their fields while the comprehensive team coordinates and organizes cross-field disruptive technology identification and evaluation. In the course of the

research, priority should be given to major disruptive technologies and rising issues concerning the state and society, while focusing on the scalability and application of potential disruptive technology.

4.4 Measures and recommendations

The measures and recommendations primarily include two aspects. First, leveraging China's scientific and technological developments, major economic and social needs will be stratified and classified, while the disruptive technologies will be identified and screened by each research team, resulting in the selection of several key technological directions for the country. Second, based on China's national conditions and the status quo of related fields, measures and policy recommendations for disruptive technology development must be studied, and recommendations for the development conditions and policy environment must be proposed to develop disruptive technologies that need to be supported and led by China. However, making such recommendations on topical in-depth strategic research with respect to disruptive technologies is particularly complex and requires further evaluation and analysis. Policy research will focus on the comprehensive team, supplemented by various field teams; this will require the involvement and participation of strategic experts, management experts, economic experts, social-science experts, and corporate executives to improve the scientific-ness and feasibility of the policy research.

5 Project progress

Under the guidance of the academicians, the project team is working closely together, and research is steadily advancing. By the receiving date of this paper, the in-depth research of each field will have been completed, and work on the comprehensive integration stage will have officially commenced. In other words, progress was achieved in stages.

The concepts and connotations of disruptive technology have been systematically and thoroughly studied, and a conceptual framework from a national perspective has been formed. This is a big step toward understanding disruptive technological concepts. Using literature analysis and bibliometrics, the project team has analyzed the evolution of disruptive concepts and innovations and summarized the development of these concepts. By analyzing the history of science and technology, the roles and laws of disruptive technology in the long-term transform chain of "science-technology-economy" have been investigated. By attaching equal importance to analyzing the "global situation" and "separate field," multi-level and multi-dimensional case studies have been conducted, resulting in the identification of dozens of disruptive technologies. The characteristics of production, growth, and transformation have been summarized. Useful advice for disruptive technology identification, prediction, cultivation, and demand creation has also been obtained. Furthermore, a disruptive technological concept framework based on the national position and perspective has also been proposed. It provides useful references for the country to grasp the laws of disruptive technology and conduct strategic decision-making and deployment related to disruptive technology.

Timely and comprehensive disruptive technology development tracking has been conducted. Platforms and channels for tracking research and promotion have been established to provide permanence. Leveraging experts and intelligence agents, the team has focused on the principles of "overall coverage, following-up key points, open channels, and scientific methods." The dynamics of advanced national agencies, research organizations, business entities, and trends in disruptive technologies in various fields have been comprehensively tracked and analyzed. The *Disruptive Technology Express* has been published 14 times, and corresponding websites and the official WeChat account are available to relevant ministries, military departments, the CAE, academicians, and other social institutions; the project has produced noticeable effects. Some opinions agreed on by the state have already played a role in the strategic direction of disruptive technology development.

Disruptive technology prediction and identification methods have been initially proposed, and several major disruptive directions have been selected. By referring to the research and summary of disruptive technology identification and evaluation methods at home and abroad, a disruptive technology identification and prediction method based on technological maturity, product maturity, and market maturity has been established by the method-and-tool research team (i.e., the engineering management team). Major potential disruptive technology directions in each field have been catalogued by various teams with the support and experience of academicians and experts. Some field teams have emphasized the development of quantum technology, artificial intelligence, gene-editing technology, and other long-term and global disruptive technology directions. Some teams have focused on current issues such as stem-cell research, micro-electro-mechanical systems technology, intelligent building information modeling and construction, and other such directions. Some field teams have focused on bottlenecks and material limitations, proposing further research directions for graphene, metamaterials, and other material technologies to address the weaknesses in key areas and core technologies. Development in these directions is very important to achieve parity and superiority in the relevant fields, to seize the strategic initiative in the future, and to support long-term sustainable development of China's economy and society.

Through research, a team of dozens of scientists, entrepreneurs, sociologists, and management experts from hundreds of organizations has been established. Academicians form the core of this team. With structured, professional, collaborative, and efficient teamwork, this team is featured with a "strong core and wide-range

support.” Corresponding working methods and mechanisms have been developed, and good communication and collaboration with government, research institutes, and businesses have been formed. A platform for the strategic research of disruptive technology science and engineering has been developed.

While affirming these achievements, we are clearly aware that there are great differences in the understanding of disruptive technologies within the community, and even within the project team. Often, there are strong uncertainties and a lack of consensus in the research process; however, this phenomenon is welcomed. There are cases where the applications of methods and the strategic research are not enough, which implies the need for continuous improvement.

6 Conclusion

This project is the first comprehensive and systematic strategic research project in the field of engineering and technological disruptive capabilities in China. It has high strategic value, wide coverage, and strong systematicity, and it meets the strategic, scientific, and feasibility requirements. The project team recognizes the complexity and the arduousness of the planning and research process. Further, during project development, the international competitive environments and global science and technology are changing rapidly. General Secretary Xi Jinping emphasized that, with key generic technologies, cutting-edge technologies, modern engineering technologies, and disruptive technological innovation breakthroughs, we dare to take the road our predecessors did not take, and we strive to achieve key control of core technologies and to take the initiative in development and innovation [3]. Therefore, the strategic research of disruptive technology should be supported as long-term work. In our follow-up article, we will focus on the high-level design of the strategic research project and strengthen the system design and collaborative organization of each round of research and long-term strategic research; we will then seek to enhance the connections between strategic research and technological in-depth research in key areas. We will also focus on the continuous improvement of the systems, the science, and the strategy of this research with the goal of supporting national decision-making in a more forward-looking and effective way, making positive contributions to the promotion of science and technology.

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