

The Strategic Connotations of and Policy Enlightenment Offered by the Concept of Disruptive Technology

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Abstract: The concept of disruptive technology has been extensively discussed since its introduction. However, because of the different research perspectives used, there is no widely accepted definition. As disruptive technology has transformative effects, such as defining an era and reconfiguring existing patterns, it plays an increasingly significant role in national strategy. Understanding disruptive technology from a national perspective has practical significance in terms of guiding the development of disruptive technology. After exploring the concept of disruptive technology from different perspectives, this study shows that developing a disruptive technology from a national perspective opens up a new path based on new principles, combinations, and applications of science and various technologies. A strategic innovative technology will reorganize the value network of traditional industries and decisively affect the upgrade of social technology systems; it may also reconstruct present national foundations, capabilities, and structures. Further, a deconstruction framework of disruptive technology is proposed from the perspectives of source, structure, span, scale, level, and path. On the basis of these aspects, this study focuses on a combination of frontier research and practical use, as well as the process, the balance between the present and the future, innovative management modes, and strategic research required to develop a disruptive technology from a national perspective.

Keywords: disruptive technology; concept; national perspective

1 Introduction

At present, a major breakthrough in science and technology is urgently needed to provide strong support for national competition and social development; further, the evolution of science and technology is coinciding with the onset of a critical period in another long-term economic cycle. With the group development of technologies, characterized by interdisciplinary integration and information technology, innovation is accelerating, and the speed of change triggered by technology far exceeds social expectations. In this context, the innovation activities centered on the concept of disruptive technology have a revolutionary significance for military, science and technology, industry, and social development owing to its out-of-the-box and game-changing features; so, these activities are a matter of great significance for society worldwide. The United States is the first country to have

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carried out research and development of disruptive technology. The Defense Advanced Research Projects Agency (DARPA), which has successfully developed disruptive technologies, aims to achieve technological breakthroughs and prevent technology surprise; further, it has achieved remarkable success in the creation and application of disruptive technology to meet military demands. China attaches great importance to disruptive innovations. General Secretary Xi Jinping pointed out in the report of the 19th National Congress that it is necessary to accelerate the development of an innovative country and highlight key common technologies, leading-edge technologies, modern engineering technology, and disruptive technology innovations; this would create a country that is strong in science and technology, quality, space, network, and traffic, in addition to ushering in a digital China and a technology-driven society. Disruptive technology has also been covered in a series of important documents, such as the *National Innovation Driven Development Strategy Program* and *13th Five-Year Plan on Science and Technology Innovation*, and plays a crucial role in national strategic competition. How does one understand the strategic connotation of the concept of disruptive technology? This study analyzes the concept and its connotation and characteristics; further, it considers the development of disruptive technology from a national perspective, and derives several policy implications.

2 The origin and analysis of the disruptive technology concept

Disruptive technology has also been called “destructive technology,” and was first proposed in 1995 by Harvard professor Clayton M. Christensen in his book *The Innovator’s Dilemma*. He suggests that a new technology replaces the existing mainstream technology in an unexpected way [1]; the ideas about the destructive and transformative nature of the technology can be traced to the “creative destruction” concept put forward by the economist, Joseph A. Schumpeter, in 1912 [2]. The concept of disruptive technology is widely used today, and many scholars and institutions have elaborated on it according to their own research perspectives or objectives.

2.1 Academic representative views

Scholars have different definitions of disruptive technology based on different research perspectives. For instance, Danneels et al. [3] argue from the product/technical perspective that a disruptive technology changes the basis of competition by changing the performance metrics to which companies adhere. Anderson et al. [4] believe that a disruptive technology, as an emerging alternative technology, can destroy the original technology trajectory, break the original technology life cycle, and form a new technology trajectory. From the strategic process perspective, Chen et al. [5] believe that disruptive technology destroys existing competitive rules of the enterprises and changes the requirements of existing markets by exploiting new technologies, products, processes, services, or business models throughout its innovation process.

2.2 Representative views of think tanks

The Center for a New American Security (CNAS) defines disruptive technology as a technology or technology group that can completely upset the military balance among rivals. Once such technology is applied, the combat style will change dramatically, and related policies, regulations, and organizations will fail.

Based on the study of disruptive technology in the military field, the Fraunhofer Institute for Technological Trend Analysis believes that disruptive technologies refer to those technologies that can “change existing rules.” Compared to existing technologies, their performance or function achieves a major breakthrough; further, their future development gradually replaces the existing technologies, and then changes the combat mode or rules [6].

McKinsey Global Institute defines four characteristics of disruptive technology in its report, *Disruptive technologies: Advances that will transform life, business, and the global economy*. First, it can dramatically change the price and performance of a product in an industry. Second, it has extensive influence on an industry and its enterprises. Third, it has a profound influence on the social economy. Fourth, it has the potential to significantly change the future trajectory of humanity.

2.3 Representative views of the government and military agencies

Some government departments or military agencies exhibit a conceptual understanding of disruptive technology in their strategic documents. DARPA, known as the disruptive technology incubator, believes that disruptive technology is a cutting-edge technology that “can change the rules of the game”; it leads to the development of

weapons and equipment through original concept innovations, and the creation of decisive disruptive effects in future wars [7]. In the implementation of the IMPACT program, Japan proposed that disruptive technology promotes significant changes in industry and society but may lead to enormous risks. In addition, Alan R. Shaffer, director of Plans and Programs Office of the Director of Defense Research and Engineering, pointed out that a disruptive technology first enters the low-end market at a low cost; however, a low-end market and low cost are not the key factors for the defense system, as pointed out in the report *Disruptive Technology: An Uncertain Future* in 2005 in the American 6th “Science and Engineering Technology” Annual Conference. “Disruptive technology ‘derives’ from existing technology systems and ‘evolves’ into new dominant technologies, thereby replacing existing technologies and making radical change of the balance of military power structure, foundation, and capabilities” [8].

The above viewpoints show that there is no agreed definition of disruptive technology and it is interpreted according to one’s perspective. There are differences and similarities among these three views. They are all closely related to the common features of disruptive technology, and emphasize the evolutionary curve, with different approaches to change the technology trajectory and the destructive effect of unexpectedly subverting the incumbent. The differences are based on the fact that academic views are mainly generated from observations and case studies of competitive situations in the commercial or industrial sector; further, they emphasize that disruptive technology and its innovation are primarily based on the challenges by new entrants to incumbents, thereby bringing about new products, industries, or market models. The think tank views emphasize the source, classification, characteristics, disruptive methods, and applications of a disruptive technology based on their own positioning and user needs. The views of the government and military agencies are based on national policies, emphasizing the technical attributes, as well as the cutting-edge and breakthrough advantages of disruptive technology. They consider the resulting disruptive effects on the existing foundations, capabilities, and structures of state power (military power) and highlight the strategic role of disruptive technology in upsetting the status quo and establishing the country’s absolute competitive advantage.

It can be seen that disruptive technology is interpreted by the specific agencies based on their own positioning and demands, and the interpretations diverge from the original meaning of Clayton M. Christensen, who thinks that, in the commercial field, a disruptive technology enters the low-end market and destroys the market position of the incumbent. In the field of national defense, a disruptive technology leads to a complete change in technologies, capabilities, and military structure. In the field of science and technology, it changes the existing scientific or engineering concepts, and poses a challenge to the traditional paradigm. The diverging views about this concept show that it has spread from the field of market competition to the field of national defense and national development of science and technology; it has gradually developed to the level of national strategy. Based on the above analysis, we posit that disruptive technology from the national perspective is based on new principles, new combinations, and new applications of science and technology. This leads to zero returns or a reconfiguration of the value network of traditional industries, a decisive influence on the upgrade and transition of the social technology system, and strategic innovations in the country’s existing foundations, capabilities, structures, and so on.

3 The strategic connotations of disruptive technology

Reviewing the development process of disruptive technology in the history of science and technology, and studying the factors determining its evolution, along with the transformative and destructive strategic effects emerging from the current disruptive technology, we can gain the following understanding of the connotations of disruptive technology.

3.1 Disruptive technology has diverse sources

Disruptive technology has four important sources. First, a major scientific breakthrough can produce a disruptive technology. Once this type of technology emerges, it will gain broad consensus and rapidly penetrate and integrate into various fields, often becoming a major technology that defines the times. This type of technology is important, but rare. Second, disruptive technology is generated from integrated innovation. This type of technology created through cross-border integration of new technologies with many existing technologies changes the industrial structure and disparity in strength. Third, the disruptive application of technology can constitute a disruptive technology. Interdisciplinary, cross-domain, or unconventional applications of traditional

technology often have disruptive effects in the application domain and constitute a disruptive technology. As society enters the era of “technology explosion” and new scientific research paradigms, as represented by big data, emerge, a growing number of such technologies are getting involved. Further, their scope is becoming wider, and the process more complex; furthermore, the speed is increasing, as in the Internet platform technology. Fourth, solving problems by means of disruptive ideas leads to a disruptive technology (problem-oriented). This approach is prevalent in current business innovations, such as SpaceX’s recyclable rocket, a new type of disruptive technology whose great success is based on experimental ideas. This concept has also led to the rise of the “first development, then re-study” innovation model. As regards this type of technology, most people first dislike it, then they do not understand it, and last they are unable to keep pace with its development. Because of this, they are totally unprepared for its impact.

3.2 Disruptive technology has a systematic technical structure

The disruptive technology is a technology group or technology system with a complex internal structure. From the spatial perspective, disruptive technology includes a complex technology group of leading technology, assistive technology, and supporting technology across multiple disciplines and fields. On the one hand, these technologies often develop together, and do not mature at the same time. Any technology can constrain or boost the development of a disruptive technology. On the other hand, these technologies often do not belong to the same field, or even the same region or country, and are destined to be accompanied by a large number of technology transfers, technology integration efforts, and secondary innovation; this is a complex process, giving rise to a large number of opportunities. From the time perspective, the growth of disruptive technology has been similar to that of other technologies, such as laboratory technology, prototype technology, and commercial or military application technology, in that it has different technical forms. The transformation into each new form means that it not only faces the fierce technology and application competition from the original sustainable technology, but is also accompanied by the transfer and transformation—a result of complex and dynamic technology selection and adaptation—of the technical subject.

3.3 Disruptive technology innovation has the conflict in technology and management

As a revolutionary force that can take “investment, industry, technology, talents, and rules” of the traditional industry back to its origin, the competition with the technology it replaces is not only the inherent competition between the new and old technology systems, but includes the conflicts related to technology and management in the process of disruptive technology innovation. The first is the technology system conflict. As a new revolutionary technology, the disruptive technology has a huge conflict with the existing technology system during its growth process. On the one hand, it is not found suitable for the supporting infrastructure and industrial system of the existing mainstream technology, and finds it difficult to develop in the existing system; on the other hand, its development and growth will change and subvert the existing system’s return and even make it zero. The conflicts in the technology system determine whether the new technology will have a long growth cycle, during which it may face many challenges, strong uncertainty, and high risks; these will test the decision-makers and also give valuable strategic opportunities to the latecomers. The second is the management system conflict. The old management system will hinder or even exclude the development of a disruptive technology. The management system is matched with the management objective. The existing management concepts, values, resources, and processes of the organization often do not adapt to the developments brought about by a disruptive technology. In the face of the changes disruptive technology brings, the company showing excellence in its original trajectory and good management will suffer failure more quickly. Industry giants, who are dominant in talent, technology, and capital, often end up as the losers of disruptive changes. For example, Kodak “invented the digital camera but was disrupted by the digital camera.”

3.4 Disruptive technology has the evolution stage and obvious time scale

The disruption of disruptive technology is not a one-step process but a long-term evolutionary process with time-scale characteristics that need to undergo stages of gestation, germination, incubation, formation, growth, and maturity. This is consistent with the general life cycle of innovation and also has the evolutionary characteristics of discontinuous nonlinear step growth and eruption at the long-term preparation stage. The process of disruptive

technology innovation contains several major breakthroughs in core technology, driving the industry transition along the path of niche products (niche market) to intermediate products (intermediate market) and, finally, to mainstream products (mainstream market), with obvious stage eruption points. In this process, the recognition and understanding of some turning points, such as the discovery and dissemination of new principles (scientific breakthrough), the invention and bifurcation of new technologies (technical bifurcation), and the creation and locking of new industries (industrial locking), are of great strategic significance.

3.5 Disruptive technology has levels in response to disruptive effects

The influence of disruptive technology takes place at multiple levels. Depending on their intensity, there are three types of innovations, and the differences in disruptive scope lead to big or small disruptions. Whether big or small, the paradigm change of the technical economy refers to the disruptive impact on the military, economy, science and technology, social macro structure, and operation mode; the industrial system change refers to the replacement of the old technology system through a reconstruction of an industry or field's technology system structure and operation mode. Technology change refers to the replacement of the traditional technology by breakthrough changes at the product/process technology level.

3.6 Disruptive technology has multi-path market entry methods

Christensen [1] believes that “disruptive technology uses the entry method of low cost–low performance that depends on product innovation and will initially enter the low-end or marginal market or new market, with a bottom-up disruptive path, and simple, convenient and cheap initial stage.” Correspondingly, high-end disruption—an important type—uses high cost and high performance combination as the method of entry. It relies on technological breakthroughs to significantly improve the performance of mainstream products, while, at the same time, causing a major breakthrough in the performance of other new products; using a higher initial price, it enters the high-end market and follows a top-down disruptive path [9]. In addition, creating innovative business models by changing the combination of value chains to disrupt existing value chains is also another market entry strategy. Grasping the characteristic conditions of different entry paths has strategic value for the selection and cultivation of disruptive technology, as per different needs.

Disruptive technology has “multi-source, structure, span, scale, level and multi-path” as its connotations. A deconstruction framework is acquired from the perspective of structure and process. For the organization, the characteristics of disruptive technology, such as source mutation, development conflict, and effect change, highlight the fact that its strategic values are different from those of the general technology; this provides the strategic connotation to understand the disruptive technology concept from the national perspective.

4 Policy implications of the development of disruptive technology from the national perspective

Disruptive technology is the leading force for realizing first-mover advantage and technology surprise; bringing about all-round changes in economic operation, social management, and military struggle; and profoundly affecting the overall situation of national security and development. The country is not only a spatial area for disruptive technology innovation, but also an important source for strategic guidance and governance. With the increasingly profound influence and extensive scope of disruptive technology change, the role of the country is becoming increasingly prominent. Through the disruptive technology concept and connotation analysis, the author presents the following implications of the development of disruptive technology from the national perspective.

4.1 Development of disruptive technology should focus on the combination of frontier and reality

From the definition of disruptive technology given by its government agencies, such as DARPA, it can be seen that the United States positions the disruptive technology as the cutting-edge technology, and maintains its leading position in the latest military technology through original concept innovation, thereby leading the disruptive change in national capacity base and structure. Its starting point is to upset the status quo and establish an absolute national advantage. China is still in a period of high-quality development and transformation. The Sino-US trade war has further highlighted the shortcomings of the science and technology economy. Thus, innovation-driving development becomes a pressing need. In contrast to the guiding ideology of absolute superiority in the United

States, China's understanding of disruptive technology considers the possibility of focusing on cutting-edge exploration and seeking a leading global position; at the same time, it also needs to use the problem to drive the goal orientation and vigorously eliminates the imbalance and inadequacy of China's development, making breakthroughs in key core technology areas. For example, China has chosen to develop disruptive frontier or emerging technologies, such as quantum communication and artificial intelligence. At the same time, it has also achieved autonomous and technological breakthroughs by means of the introduction, assimilation, and ultra-large-scale integrated innovation in major high-speed rail projects. These breakthroughs have led to the quick implementation and popularization of high-speed rail projects; further, they have made the high-speed rail a revolutionary force driving the overall breakthrough in the science and technology, as well as the land transportation economy, and meeting a wide range of social public consumption needs [10]. Therefore, the starting point of China's development of disruptive technology at this stage is the combination of frontier and reality, with a focus on ensuring that: (1) disruptive technology leads to an overall breakthrough in China's science and technology economy (change in capabilities); (2) the demand for application of the disruptive technology comes from the industry of overriding significance or a social consumption industry (problem or demand-oriented); (3) the disruptive scope covers the overall national or regional industrial system, causing a change in the social, technological, and economic paradigm (an extensive role); (4) the fundamental driving force of disruptive technology arises from frontier exploration and pioneering breakthroughs in the basic science field (a leading frontier).

4.2 Development of disruptive technology should focus on process and maintain strategic focus

The disruptive process of a disruptive technology takes place over the long term and is characterized by twists and turns, as well as uncertainty. The fact that it is difficult to reach the goal in one step and foresee the future is a test for the decision-maker. The disruption of cathode ray tube (CRT) by liquid crystal display (LCD) is a model case. The LCD disruption process included scientific principle discovery, technological breakthroughs, industrialization, large-scale application, maturity, and recession. LCD originated in the United States and Europe, was changed in Japan, disrupted in Korea, and outpaced in China, over a more than 120-year period [11]. In this process, a country's strategic vision of choosing a disruptive technology and its determination to foster development have played very important roles in deciding the fate of that country. The evolution of disruptive technology is not linear. For the country, the recognition and understanding of some turning points, such as the discovery and dissemination of new principles (scientific breakthrough), the invention and bifurcation of new technologies (technical bifurcation), and the creation and locking of new industries (industrial locking), are time windows for formulating and adjusting policies, and different degrees of intervention are required, depending on the development status of technology and market at different stages. This can help the disruptive technology to achieve complete disruption by becoming mainstream. However, the disruptive technology innovation encounters the double bottleneck of "Death Valley" and "Alexander Dilemma," making it difficult and risky to develop and transform; this tests the strategic confidence and influences the strategic focus [12]. Therefore, in the choice and cultivation of disruptive technology, the country should fully understand the evolutionary law of disruptive technology and the characteristics of stage eruption on a time scale, give strategic vision and exhibit sufficient patience, seize the characteristics of market failure and system failure at different stages, and grasp the opportunity to make timely interventions.

4.3 Development of disruptive technology should focus on achieving a balance between the present reality and future

Disruptive technology leads to conflicts related to technology and management during the disruption process; it causes disruptive innovation, depending on the existing capability base and structure of the country. The inherent conflict between its own development and traditional forces will also produce a conflict between the present reality and future during national decision-making; this conflict has two aspects. First, the technical reserve and the potential needed for the development of disruptive technology requires sacrificing real benefits. The preparation for, and formation of, disruptive technology encounters conflicts related to technology and management of existing mainstream systems. The country accelerates the withdrawal of traditional forces through strong technological investment or government intervention, when necessary, to create a space for conflict resolution that fosters the development of a disruptive technology; this leads to sacrificing present reality for the future. Second, the

preparation for disruptive technology needs to have realistic basic conditions. Alan R. Shaffer [8] believes that “disruptive technology is ‘derived’ from the established systems and technology systems, and ‘evolves’ into new leading technologies.” The development of a country’s existing capability base and structure is the source of disruptive technology. It is difficult to generate disruptive technology from a weak foundation. However, the conflict between technology and management caused by a disruptive technology will be a destructive force that may reduce the existing capabilities of the organization to zero, and bring about a reconfiguration of production relations, as well as great changes in its social nature.

As a fundamental force to reconstruct future patterns, a disruptive technology provides an important way for the country to balance present reality with the future. Developing disruptive technology requires a dialectical treatment of the conflict between technology and management, and a need to strive for a balance between present and future realities. A satisfactory job can be done in the distribution of resources, policies, and strength from the spatial layout, and grasping the optimal window of entry and exit from the strategic timing. Both passive “understanding of and adaption to the development of disruptive technology” and active “recognition, creation, and leading the development of disruptive technology” will enhance the country’s capability to cope with the future and position the country favorably in future competition.

4.4 Development of disruptive technology should focus on the innovative management mode

Developing disruptive technology not only faces profound conflicts between technology and management, but also needs to balance the relationship between the present reality and future. Christensen believes that innovators often fall into the “innovator’s dilemma” in the face of disruptive technology innovation. Organizational innovation is the basis of disruptive technology innovation. Based on this characteristic of disruptive technology, the United States has adopted the unique dual-organization management mode, as in DARPA, to make disruptive technology innovation activities overcome the inertia of organization structure, as well as the interference of mainstream culture, through the relative independence or separation of organization, culture, resources, and capabilities; this leads to success of special zones “outside the system.” Most of these special zones outside the system have common characteristics. For example, in mission positioning, they are on a mission to innovate and mobilize the resources of the whole society to produce innovation in the entire ecosystem. In business positioning, they are beyond all businesses and departments and do not specify any direction. The project is only carried out at the budding stage and transferred to other departments after being verified; thus, it is not tied to the innovation chain. In the institutional mechanism, the special “institution” with relatively independent or separate operations does not enter the existing value network (resources, processes, and values). The institution has a small scale, flat management, and small and scattered projects.

Faced with the multiple conflicts caused by disruptive technology, China needs an innovative management mode. In the macro system, a relatively independent and disruptive technology innovation plan is established outside the existing science and technology plan management system to support challenging and high-risk innovation activities and explore technologies that can fundamentally transform economic growth and social development. The mechanism’s operation is boldly innovative, and the requirement definition, project establishment, resource allocation, organization management, assessment, and evaluation of disruptive technology are continuously explored and optimized through multiple actions and tests. Industrial applications strengthen forward-looking and strategic guidance on industrial policies and promote the innovative transformation of disruptive technology. The environment is constructed to improve the integrated system of “military, production, study, research, and application,” bringing forth new ideas for the diversity of the “rain-forest ecology,” and forming a fertile ground conducive to disruptive innovation from the thought, source of demand, and the application terminal.

4.5 Development of disruptive technology should focus on strategic research

Disruptive technology is a new technology with significant strategic features that replace existing dominant technologies in an unexpected way. In the United States, many well-known institutions, ranging from government departments to private think tanks, have carried out strategic research on the different positioning requirements of disruptive technology based on different perspectives and levels, forming a research ecosystem of a certain scale, and providing a wealth of wisdom for decision-making and deployment by the American government. In particular, DARPA proposes to use original concept innovation to lead the development of weapons and equipment, ranging

from future scene design, which brings about disruptive technology strategy research, to future scene application and concept innovation, which establishes a commanding height of national disruptive technology strategic thinking competition; this, in turn, poses serious challenges to national strategic research capabilities at various levels. The subjective will regarding the country's development and the objective laws of the historical process all indicate that China has entered a new stage, wherein it systematically considers disruptive technologies, and it is necessary to carry out strategic research of disruptive technology at the national strategic level, and plan to change the follow-up path; this is an important starting point to outpace the leading trajectory, change low-end locking dilemma, lead the high-quality development of the economy, and become a world power in science and technology. Shortly after the start of China's strategic research on disruptive technologies, the National High-end Think Tanks, academia, and think tank research institutions, such as the Chinese Academy of Engineering, began to carry out related work.

At present, disruptive technologies are emerging in many fields. The country should attach great importance to research on disruptive technology by taking a comprehensive view, enhance scientific insights and strategic understanding of disruptive technology, and further strengthen the top-level design and overall coordination of cutting-edge technology innovations. Further, it should establish monitoring, assessment, and early warning mechanisms for disruptive technologies to identify the technology surprise that may adversely affect national security, as well as its sources, and predict the resulting economic, military, and social risks. Furthermore, it should strengthen governance research on transformative risks brought about by disruptive technology, adopt forward-looking prevention and restraint guidance for risks resulting from disruptive technology applications, such as national security, employment imbalance, and ethics and morality, and realize responsible technology innovation to ensure safety.

5 Conclusions

Disruptive technology has an objective existence in the history of science and technology. Taking a long-term view, it is an important engine that has triggered all previous industrial revolutions and has an important historical position and strategic role. The concept of disruptive technology provides clarity on the important practical role of disruptive technology in the history of science and technology. At present, China not only passively adapts to disruptive technology and tries to keep pace with its development, but also actively takes the lead in identifying and creating disruptive technology. We also find that disruptive technology is a relatively niche technology, having a low probability of success, in the science-technology-economy transformation cycle. Once its disruption is successful, a disruptive technology is transformed into a sustainable technology, and society enters the phase of a relatively steady-state operation. Therefore, at the national level, we must accurately grasp the strategic connotation of disruptive technology; attach importance to, and bring into play, its inherent strategic effect; and, at the same time, provide guidance for the reasonable and coordinated development of other innovative technologies from a global perspective.

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