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Summary of Research Progress and Methods of Disruptive Technology in China and Abroad

Sun Yongfu [1], Wang Liheng [1], Lu Chunhua [2,3], Sun Zongtan [2], Wang Kunsheng [2], Xu Yuan [2]

1. Chinese Academy of Engineering, Beijing 100088, China
2. China Aerospace Academy of Systems Science and Engineering, Beijing 100048, China
3. School of Economics, Peking University, Beijing 100871, China

Abstract: At present, technological innovation has entered a uniquely intensive and active period worldwide with the constant emergence of major disruptive technologies. These disruptive technologies have accelerated the iteration of new industries and formats, are profoundly influencing the balance among national powers, and are expected to contribute in reshaping the world economic structure and the international competition pattern. To seize this current opportunity, countries are now actively engaged in early identification and nurture of disruptive technologies. In this paper, the research reports on disruptive technologies in China and other countries are extensively surveyed, and the research progress and methods of disruptive technologies are summarized, analyzed, and evaluated. This paper also suggests certain ideas to promote the scientific development of the research on disruptive technology in China, including the establishment of specialized think tanks by concentrating superior resources and the establishment of a technology evaluation system.
Keywords: disruptive technology; assessment and prediction; methods

1 Introduction

Currently, global science and technological innovation has entered an era of unprecedented activity, demonstrating rapid development and a high degree of integration. All major countries are focused on technological innovation, especially disruptive technological innovation, as the core of their overall development. They have actively seized the commanding heights of science and technology to promote comprehensive innovation and further strengthen the stamina of economic growth and the active position of related industries in the global value chain. For example, a series of major disruptive technologies created by the United States under the disruptive technology normalization research mechanism have resulted in the transformation of related industries and ensured that United States has maintained a long-term leading position in the field of technological innovation and has aided in industrial upgradation in related fields. Russia set up the “Advanced Research Foundation” to support and research disruptive technologies. UK improved the industry–university–research system to support the development of future disruptive technology. Japan has implemented a “Disruptive Technological Innovation Program” to promote the development of disruptive technologies with significant social and industrial influences [1].

The economy of China is currently in the process of transforming the developmental mode, optimizing the economic structure, and transforming the growth momentum. A disruptive technology with significant social and

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Corresponding author: Sun Yongfu, Chinese Academy of Engineering, Academician. Major research field is railway engineering management. E-mail: yongfusun@163.com
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industrial influence can promote significant regulations of the economic and industrial structures and become the most important innovation-driven development and can result in national competitiveness. China has launched several disruptive technology identification and prediction works in recent years and has achieved considerable results. However, in general, the existing research work on disruptive technology and its research methods still requires improvements; therefore, it is necessary to summarize and analyze the results of the relevant foreign research to perform disruptive technology prediction for relevant domestic institutions.

2 Summary of research progress and methods of disruptive technology in China and other countries

The project team explored foreign disruptive technologies and compiled certain industry-related technologies. Initially, they conducted research on foreign disruptive technology identification, assessment, and prediction methods. The absorption of the results of this research is the source of the research presented subsequently.

2.1 Summary of research progress and methods of disruptive technology in China and other countries

The project team tracked the strategic plans, documents, and forecast reports related to disruptive technologies released in the past five years, including reports from government agencies, different industries, think tanks, and science and technological research. They also analyzed the disruptive technologies related to various industries that were proposed by foreign countries (Table 1).

Table 1. Disruptive technologies related to different industries that were proposed by foreign countries.

Field	Technology	Documents and reports referring to the technology
Information technology	Big data	Defense Advanced Research Projects Agency's (DARPA's) *Breakthrough Technologies for National Security*, UK's *Technology Foresight 2030*, UK's *Future of Technology and Innovation 2017*, Korea Institute of Science and Technology Evaluation and Planning's (KISTEP's) *Ten Emerging Technologies* (South Korea), Kearney big data technology report, Goldman's nine major disruptive technologies
	Quantum technology	DARPA's *Breakthrough Technologies for National Security*, DARPA's *Forward to the Future: Visions of 2045*, US Army's *Emerging Science and Technology Trends 2016–2045*, EU's Quantum Technology Flagship Project, UK's *National Strategy for Quantum Technologies*, Japan's Quantum Communication Technology Program, Thomson Reuters' *The World in 2025: 10 Predictions in Innovation*, Gartner's *Hype Cycle for Emerging Technologies, 2017*, *Nature*'s 2017 Outlook, *MIT Technology Review*
	Artificial intelligence	UN's *Future Outlook*, Center for Strategic and International Studies (CSIS) *Defense 2045* Assessment Report, DARPA's *Forward to the Future: Visions of 2045*, KISTEP's *Ten Emerging Technologies* (South Korea), US's *National Artificial Intelligence Research and Development Strategic Plan*, Gartner's *Predicts 2018: Artificial Intelligence*, McKinsey's *Artificial Intelligence, the Next Digital Frontier?*, PwC's *Measuring the Impact of Artificial Intelligence*, PwC's *Exploring the AI Revolution*, Bank of America Merrill Lynch study on *Robot Revolution*, Harvard University's *Artificial Intelligence and National Security*, Stanford University's *Artificial Intelligence and Life in 2030*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, Gartner's *Top 10 Strategic Technology Trends for 2016*, Gartner's *Hype Cycle for Emerging Technologies, 2017*, KPMG's *The changing landscape of disruptive technologies*, Forbes report on technological trends in 2018, Loma's *2018 Forecast*, *MIT Technology Review*
	Internet of Things	US National Intelligence Council's *Disruptive Civil Technology*, US Army's *Emerging Science and Technology Trends 2016–2045*," KISTEP's *Ten Emerging Technologies* (South Korea), Gartner's *Top Ten Strategic IT Technologies for 2015*, Frost & Sullivan's *Eight Development Trends in Networking*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, Gartner's *Top 10 Forecasts in 2020*, Gartner's *Top 10 Strategic*

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Table 1 (continued)

Field	Technology	Documents and reports referring to the technology
		Technology Trends for 2016, Gartner's *Hype Cycle for Emerging Technologies, 2017*, KPMG's *2014 Global Technology Innovation Survey*, KPMG's *The changing landscape of disruptive technologies*, Forbes report on technological trends in 2018, *MIT Technology Review*
	Virtual Reality/ Augmented Reality (VR/AR)	US Army's *Emerging Science and Technology Trends 2016−2045*, KISTEP's *Ten Emerging Technologies* (South Korea), Lieberman's *Virtual Reality Change Market Research*, Gartner's *Top 10 Forecasts in 2020*, Gartner's *Hype Cycle for Emerging Technologies, 2017*, Deloitte's *2017 Technology Trends*, Goldman Sachs report on "9 major disruptive technologies," *MIT Technology Review*
	Unmanned system	UN's *Future Outlook*, CSIS's assessment report of *Defense 2045*, Center for a New American Security (CNAS's) "game-changing" report, UK's *Technology Foresight 2030*, UK's *Future of Technology and Innovation 2017*, KISTEP's *Ten Emerging Technologies* (South Korea), Bank of America Merrill Lynch's *Robot Revolution*, *Aviation Weekly* reports, World Robotics Conference presentations, Gartner's *Hype Cycle for Emerging Technologies, 2017*, KPMG's *The changing landscape of disruptive technologies, MIT Technology Review*
	Smart City	US's *A Strategy American Innovation* in 2015, US Army's *Emerging Science and Technology Trends 2016−2045*, EU's *Energy 2020: A strategy for competitive, sustainable and secure energy*, Thomson Reuters' *The World in 2025: 10 Predictions in Innovation*
	Advanced computing technology	US's *A Strategy American Innovation* in 2015, CSIS's assessment report of *Defense 2045*, US Army's *Emerging Science and Technology Trends 2016−2045*, UK's *Technology Foresight 2030*, Gartner's *Top Ten Strategic IT Technologies for 2015*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*
	Human–machine system	US National Aeronautics and Space Administration (NASA's) "game-changing" industry day, DARPA's *Forward to the Future: Visions of 2045*, *MIT Technology Review*
	Communication technology	*2020 High-tech Strategy for German*, UK's *Technology Foresight 2030*, *Russian Federation S&T Development Strategy*, Japan's "Top Ten Most Important Technologies," *Japan Strategic Technology Roadmap*, *Aviation Weekly* reports, Rand's *The Global Technology Revolution 2020, In-Depth Analyses*
	Sensor	UK's *Technology Foresight 2030*
	System structure	Gartner's *Top 10 Strategic Technology Trends for 2016*, Gartner's *Top 10 Strategic Technology Trends for 2017*
	Cloud (computing)	US Army's *Emerging Science and Technology Trends 2016−2045*, UK's *Technology Foresight 2030*, Gartner's *Top Ten Strategic IT Technologies for 2015*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, Gartner's *Top 10 Strategic Technology Trends for 2018*," Gartner's *Predicts 2018: Artificial Intelligence*, KPMG's *2014 Global Technology Innovation Survey*, Goldman Sachs's report on "9 major disruptive technologies"
	Blockchain	Deloitte's *Technology Trend 2017*, Forbes report on technological trends in 2018, Gartner's *Predicts 2017/2018/2020*, Gartner's *Hype Cycle for Emerging Technologies, 2017*
	Digital twins	Gartner's *Predicts 2018: Artificial Intelligence*, Forbes report on technological trends in 2017, Loma's *2018 Forecast*
Energy	Renewable energy system	UN's *Future Outlook*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, *MIT Technology Review*
	Biofuels	US National Intelligence Council's *Disruptive Civil Technology*, EU's *Energy 2020: A strategy for competitive, sustainable and secure energy*
	Clean energy	US National Intelligence Council's *Disruptive Civil Technology*, US's *A Strategy for American Innovation* in 2015, *2020 High-tech Strategy for German*, UK's *Technology Foresight 2030*, Florida State University's "Artificial Photosynthesis,"

Table 1 (continued)

Field	Technology	Documents and reports referring to the technology
		Rand's *The Global Technology Revolution 2020, In-Depth Analyses*, Thomson Reuters' *The World in 2025: 10 Predictions in Innovation*, *Global Science* report, *MIT Technology Review*
	Energy saving technology	US's *A Strategy for American Innovation* in 2015, UK's *Technology Foresight 2030*, *Russian Federation S&T Development Strategy*, *Global Science* report
	Energy mining technology	Japan's "Top Ten Most Important Technologies," McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*
	Energy storage technology	McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*
	Smart grid	Accenture's "smart grid" research
Biology	Synthetic biology (technology)	UN' *Future Outlook*, CSIS's assessment report of *Defense 2045*, DARPA's *Breakthrough Technologies for National Security*, US Army's *Emerging Science and Technology Trends 2016−2045*, UK's *Technology Foresight 2030*, US *National Bioeconomy Blueprint*
	Human enhancement (downgrade)	CNAS's "game-changing" report, US Army's *Emerging Science and Technology Trends 2016−2045*, *UK Synthetic Biology Strategic Plan 2016*, *UK Bioenergy Strategy*, CNAS's *Game Changers: Disruptive Technology and U.S. Defense Strategy*
	Human brain and neural technology (including brain-computer interface)	US's *A Strategy for American Innovation* in 2015, DARPA's *Forward to the Future: Visions of 2045*, EU's "Future and Emerging Technology Flagship Project," UK's *Technology Foresight 2030*, EU's "Brain Project," Gartner's *Hype Cycle for Emerging Technologies, 2017*, *MIT Technology Review*
	Life support technology	NASA's "game-changing" industry day
	Gene technology	US Air Force's *Technology Vision 2030*, UK's *Technology Foresight 2030*, US *National Bioeconomy Blueprint*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, Thomson Reuters' *The World in 2025: 10 Predictions in Innovation*, *Nature*'s 2017 Outlook, *MIT Technology Review*
	Biometric system	US Air Force's *Technology Vision 2030*, UK's *Technology Foresight 2030*
	Bioinformatics	US *National Bioeconomy Blueprint*
	Nanobiotechnology	US' *National Nanotechnology Initiative*
Nano	Nanotechnology	UN's *Future Outlook*, CSIS's assessment report of *Defense 2045*, NASA's "game-changing" industry day, *2020 High-tech Strategy for German*, UK's *Technology Foresight 2030*, *Russian Federation S&T Development Strategy*, *Japan Strategic Technology Roadmap*, US' *National Nanotechnology Initiative*, *MIT Technology Review*
Medical	Precision medicine	US's *A Strategy for American Innovation* in 2015, US's "2015 State of the Union Address," Thomson Reuters' *The World in 2025: 10 Predictions in Innovation*
	Wearable technology	DARPA's *Forward to the Future: Visions of 2045*, Deloitte's *Life Science Trends 2020*
	Regenerative medicine	UK's *Future of Technology and Innovation 2017*, Rand's *The Global Technology Revolution 2020, In-Depth Analyses*
	Novel drugs	Japan's "Top Ten Most Important Technologies," Rand's *The Global Technology Revolution 2020, In-Depth Analyses*, Thomson Reuters' *The World in 2025: 10 Predictions in Innovation*
	Immunotherapy	Goldman Sachs report on "9 major disruptive technologies," *Nature*'s 2017 Outlook, *MIT Technology Review*
	Medical system	Japan's "Top Ten Most Important Technologies," Deloitte's *Life Science Trends 2020*, *MIT Technology Review*
	Nanomedicine	US' *National Nanotechnology Initiative*
Material	Energy storage materials	US National Intelligence Council's *Disruptive Civil Technology*
	Advanced materials	US Air Force's *Technology Vision 2030*, US Army's *Emerging Science and*

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Table 1 (continued)

Field	Technology	Documents and reports referring to the technology
		Technology Trends 2016−2045, EU's "Future and Emerging Technology Flagship Project," *2020 High-tech Strategy for German*, UK's *Technology Foresight 2030*, UK's *Future of Technology and Innovation 2017*, *Russian Federation S&T Development Strategy*, US's *National Nanotechnology Initiative*, US's *Materials Genome Initiative*, *Abbey News* report of *Six New Materials that may Change the Future*, *Aviation Weekly* report, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, *Nature*'s 2017 Outlook
High-end manufacturing	Additive manufacturing (3D, 4D printing)	UN's *Future Outlook*, CSIS's assessment report of *Defense 2045*, CNAS's "game-changing" report, US Army's *Emerging Science and Technology Trends 2016−2045*, UK's *Technology Foresight 2030*, *Manufacturing USA*, US's "Measurement Science Roadmap for Polymer-Based Additive Manufacturing," US's "Additive Manufacturing Technology Roadmap," Gartner's *Hype Cycle for 3D Printing, 2017*, Gartner's *Top Ten Strategic IT Technologies for 2015*, Roland Berger's *Additive Manufacturing*, Kearney's *3D Printing: A Manufacturing Revolution*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, Gartner's *Top 10 Strategic Technology Trends for 2016*, Goldman Sachs' report on "9 major disruptive technologies," Forbes report on technological trends in 2018, *MIT Technology Review*
	Robot (hardware)	UN's *Future Outlook*, US National Intelligence Council's *Disruptive Civil Technology*, DARPA's *Forward to the Future: Visions of 2045*, Boston Consulting Group's *Global Industrial Robot Report*, World Robotics Conference report, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*
	Advanced manufacturing technology	UN's *Future Outlook*, NASA's "game-changing" industry day, *Japan Strategic Technology Roadmap*, *Manufacturing USA*
	National manufacturing innovation network	US's *A Strategy for American Innovation* in 2015
Aerospace	Space exploration	US's *A Strategy for American Innovation* in 2015, DARPA's *Future Technology* Forum, US Army's *Emerging Science and Technology Trends 2016−2045*, *Nature*'s 2017 Outlook
	Space robot	NASA's "game-changing" industry day, DARPA's *Forward to the Future: Visions of 2045*
	Hypersonic technology	NASA's "game-changing" industry day, US Air Force's *Technology Vision 2030*, *Aviation Weekly* report, Loma's *2018 Forecast*
	Avionics equipment	NASA's "game-changing" industry day
	Satellite	UK's *Future of Technology and Innovation 2017*, *Aviation Weekly* report
	Propulsion and launch technology	*Aviation Weekly* report, *MIT Technology Review*
Others	Micro-electromechanical systems (MEMS)	US' *National Nanotechnology Initiative*
	Graphene related technology	UK's *Technology Foresight 2030*, EU's "Future and Emerging Technology Flagship Project"
	Unmanned driving	Lux's "unmanned technology" report, McKinsey's *The context of the autonomous driving technology revolution, problems and evolution*, McKinsey's *Disruptive Technologies: Advances that will transform life, business, and the global economy*, Gartner's *Hype Cycle for Emerging Technologies, 2017*, *MIT Technology Review*

These reports can be broadly divided into three categories: comprehensive reporting, special technical reporting, and technology forecasting and trend analysis. The comprehensive report is primarily a strategic report issued by governments or well-known think tanks (Table 2), which refers to disruptive technologies in multiple areas, such as artificial intelligence, robotics, biology, and energy. The special technical report (Table 3) has a relatively wide

range of sources, and each institution has proposed corresponding disruptive technical directions for specific technical fields. The technology forecasting and trend analysis report (Table 4) is primarily a summary of disruptive technologies in recent years, as well as an analysis of future disruptive technology trends.

Table 2. Reports regarding disruptive technologies in foreign countries.

No.	Publishing or research institution	Report name	Release year
1	UN	Future Outlook	2015
2	UNESCO	UNESCO Science Report: towards 2030	2015
3	National Science and Technology Council	Science, Technology, and Innovation Strategy for the 21st Century - Ensuring National Security in the United States	2016
4	National Intelligence Council	Disruptive Civil Technologies: Six Technologies with Potential Impacts on US Interests Out to 2025	2008
5	White House Science and Technology Policy Office	New Strategy for American Innovation	2015
6	United States Defense Industry Association	Top Ten Disruptive Technologies for a New Era of Global Instability	2014
7	CSIS	Defense 2045: Assessing the Future Security Environment and Implications for Defense Policymakers	2015
8	CNAS	Game Changers: Disruptive Technology and U.S. Defense Strategy	2013
9	NASA	10 Technologies That Are Changing the Game	2016
10	US DARPA	Forward to the Future: Visions of 2045	2015
11	US Air Force	Global Horizon: US Air Force Global Science and Technology Vision	2013
12	US Air Force	Technology Vision 2030	2011
13	US Army	Emerging Science and Technology Trends 2016−2045	2016
14	EU	“Future and Emerging Technology Flagship Project”	2013
15	EU	European Commission’s Horizon 2020 (H2020) multi-annual work plan	2015
16	European Council	Europe 2020: A strategy for smart, sustainable, and inclusive growth	2010
17	German Federal Ministry of Education and Research	Germany’s second technical foresight	2012−2014
18	Germany	Ideas, Innovation, Growth - 2020 High-tech Strategy for German	2010
19	UK government	Technology and Innovation Futures: UK Growth Opportunities for 2030	2010
20	UK Government Technology Office	Future of Technology and Innovation 2017	2017
21	Russia	Russian Federation S&T Development Strategy	2014
22	Japanese government	Top ten most important technologies	2013−2015
23	Japanese government	Japan Strategic Technology Roadmap	2005
24	Japanese cabinet	Science and Technology Innovation Comprehensive Strategy 2017	2017
25	KISTEP	Ten Emerging Technologies	2016

Table 3. Special report regarding disruptive technologies in foreign countries.

No.	Publishing or research institution	Report name	Release year
1	White House	National Artificial Intelligence Research and Development Strategic Plan	2016
2	Department of Defense	New Cyber Strategy	2015
3	US Government	National Bioeconomy Blueprint	2012
4	US Government	National Nanotechnology Initiative	2000
5	National Natural Science Foundation of America	Graphene-Related Technology Project	2002–2013
6	US Government	Material Genome Initiative	2012

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Table 3 (continued)

No.	Publishing or research institution	Report name	Release year
7	US Government	Manufacturing USA	2016
8	National Institute of Standards and Technology	Measurement Science Roadmap for Polymer-Based Additive Manufacturing	2017
9	USA	Additive Manufacturing Technology Roadmap	2013
10	American Institute of Health Research	Brain Plan	2013
11	The State of the Union Address	Precision Medicine Initiative	2015
12	EU	Quantum Technology Flagship Project	2016
13	EU	EU Brain Project	2013
14	UK	National Strategy for Quantum Technologies	2015
15	UK	UK Synthetic Biology Strategic Plan 2016	2016
16	UK	UK Bioenergy Strategy	2013
17	Japan	Quantum Communication Technology Program	2011
18	Gartner	Predicts 2018: Artificial Intelligence	2017
19	Gartner	Hype Cycle for 3D printing, 2017	2017
20	Gartner	Top Ten Strategic IT Technologies for 2015	2015
21	McKinsey	Artificial Intelligence: The Next Digital Frontier?	2017
22	McKinsey	Automotive Revolution - perspective towards 2030	2016
23	McKinsey	The context of the autonomous driving technology revolution, problems and evolution	2017
24	PwC	Measuring the Impact of Artificial Intelligence: Seizing the Opportunity	2017
25	PwC	Exploring the AI revolution	2017
26	Lieberman Global Institute	Virtual Reality Technology	2014
27	American Lux Research	Driverless Technology	2015
28	Kearney Report	Big data Technology	2015
29	Accenture	Smart Grid Technology	2014
30	Boston Consulting Group	Global Industrial Robot Report	2016
31	Roland Berger	Additive manufacturing–A game changer for the manufacturing industry?	2013
32	Bank of America Merrill Lynch	Robot Revolution	2015
33	Kearney	3D Printing: A Manufacturing Revolution	2015
34	Frost & Sullivan	Eight Development Trends of the Internet of Things	2017
35	UK Market Consulting	Virtual Reality Technology	2015
36	British Mobile Consulting	Virtual Reality Technology	2016
37	IDC Future Scape	Top Ten Trend Forecasts for the Global Internet of Things in 2018	2017
38	Spain's Abbey News	Six New Materials that May Change the Future	2017
39	Aviation weekly	The 9 major aerospace technology fields that the next US president must pay attention to	2016
40	Aviation weekly	16 aerospace technologies worthy of attention in 2016	2015
41	Aviation weekly	The most promising 18 aerospace technologies	2016
42	Harvard University Kennedy School of Politics	Artificial Intelligence and National Security	2017
43	Stanford University	The development trend of artificial intelligence, how artificial intelligence will integrate and influence our lives in 2030	2016
44	Florida State University	Artificial photosynthesis converts carbon dioxide into fuel	2017
45	Amazon, Microsoft, etc.	Edge Calculation	2017
46	World Robot Conference Expert Committee	Ten Most Growing Technology Outlooks in the Robotics Sector (2017–2018)	2017
47	Delphi Guest Expert	11 new technologies for autonomous car driving innovation	2017
48	Deloitte	2020 Health and Life Sciences Trend Forecast	2014

Table 4. Technology forecast and trend report regarding disruptive technologies in foreign countries**.**

No.	Publishing or research institution	Report name	Release year
1	RAND	49 future technologies	2006
2	McKinsey	12 disruptive technologies leading the global economic transformation	2013
3	Thomson Reuters	The world of 2025: 10 innovation predictions	2014
4	Thomson Reuters	12 major disruptive technological innovation directions	2015
5	MIT	MIT Technology Review	2001–2017
6	Gartner	Top 10 Strategic Technology Trends for 2019	2016
7	Gartner	Top Ten Strategic Technology Trends in 2016	2016
8	Gartner	Top Ten Strategic Technology Trends for 2017, 2018	2017
9	Gartner	Hype Cycle for Emerging Technologies, 2017	2017
10	KPMG	2014 Technology Innovation Survey	2014
11	KPMG	2017 Disruptive Technology Change Trend Report	2017
12	Accenture	Accenture Retail Technology Outlook	2015
13	Deloitte	2017 Deloitte Technology Trends	2017
14	Davos World Economic Forum	Top Ten Emerging Technologies of the Year	2012–2017
15	Goldman	Nine major disruptive technologies	After 2014
16	Global Science	7 major disruptive technologies to crack the energy crisis	2011
17	Nature	Top Ten Outlooks for 2017	2016
18	American Anti-Intelligence Director	American technology that most countries want to acquire or steal	2013
19	Silicon Valley Bank	Frontier Science and Technology Report	2015
20	US Defense Department Defense Innovation Test Group	Five leading edge technology areas of concern	2017
21	ARK	Seven most disruptive technologies	2017
22	The Verge	“World after five years” interview series	2016
23	Intel Corporation’s interview conducted by the Physicist Organization	Future technology trends	2017
24	Financial Times	Five cutting-edge technologies that change the future of mankind	2017
25	IBM	IBM Next Five in Five	2017
26	Forbes website	6 interesting observations on the 2017 forecast of technology trends	2016
27	Forbes website	5 Techno Shocks for 2018 (& a Bonus Shock)	2017
28	Forbes website	Top 17 Tech Trends for 2017	2016
29	Forbes website	9 Technology Mega Trends That Will Change The World In 2018	2017
30	Forbes website	7 Technology Trends That Will Dominate 2017	2016
31	MIT Science and Technology Review, Communist Youth League Pravda, Hawking, etc.	2017 will profoundly influence and change human technology	2017
32	Accenture	Technology Trends 2017	2016
33	New Scientist	10 major scientific and technological events that will take place in 2017	2017
34	Luo Ma	Six top technology forecasts that will affect defense and military industry in 2018	2017
35	GP Bullhound	Top Ten Technology Trends in 2017	2017
36	World Internet Conference	18 leading global scientific and technological achievements	2017
37	Frog Design	Tech trends 2017	2016
38	German "World News"	Bill Gates’ Seven Predictions for the Future of Mankind	2017

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2.2 Summary of foreign disruptive technology identification, evaluation, and prediction methods

For tracking the foreign disruptive technology, the project team summarized and analyzed the disruptive technology identification, assessment, and prediction methods conducted abroad.

2.2.1 Research on foreign disruptive technology identification methods [2]

The project team selected nine technical innovation research reports published by typical foreign institutions, summarized the disruptive technology identification methods, and divided them into five categories: literature analysis method, technology definition method, questionnaire survey method, scene simulation method, and technology roadmap method (Table 5).

The representative organizations and their research reports are: Thomson Reuters' *Open Future: 2015 Global Innovation Report*, the US Department of Defense's (DoD's) "Technology Surveillance / Horizon Scan (TW/HS)" project, the RAND Corporation's 2013 *Future Defense Technology Prospects, Insights, Analysis, and Implications* (document analysis), *MIT Technology Review* of the Massachusetts Institute of Technology, McKinsey's *12 Disruptive Technologies Leading the Global Economic Transformation*, Goldman Sachs' summary of nine major disruptive technologies (technical definition method), KPMG's *2014 Global Technology Innovation Survey* (Questionnaires), CNAS's *Game Changers: Disruptive Technology and U.S. Defense Strategy* (Scenario Simulation), NASA's *Technical Roadmap for Future Space Development* (technical roadmap method).

Table 5. Analysis of typical methods for disruptive technology identification in foreign countries.

No.	Method	Qualitative/quantitative	Input	Output	Applicability	Technical tools
1	Literature analysis	Quantitative	Technical search terms and references, patent databases	Key technical areas after data extraction, analysis and expert screening	Hot areas and trends reflecting the development of technology for quantitative and visual assessment	Knowledge map, cluster analysis
2	Technical definition	Qualitative and quantitative combination	Technical selection criteria	Key technical fields after screening	Used to identify technologies with established criteria	Expert consultation and evaluation
3	Questionnaire	Qualitative	Questionnaires targeting experts and their opinions	Expert collective judgment result	For directional technology, more comprehensive and flexible analysis	Online questionnaire and expert interview
4	Scene simulation	Qualitative	Future scene	Relative obstacles and ways of technology realization	Applicable to the identification of demand traction technology	Expert consultation and evaluation
5	Technical roadmap	Qualitative	Systematic research on future social, economic and technological development	Technology development priorities, implementation time, development path in a certain field	Technology for a certain field	Expert consultation and evaluation

2.2.2 Research on foreign disruptive technology evaluation and prediction methods

The project team selected the results of the technical evaluation and prediction research conducted by seven typical foreign institutions and divided them into five categories: technology maturity curve method, technology maturity evaluation method, quality function development method, scenario analysis method, and social trend focus method. (Table 6).

The representative organizations and research results are: Gartner's *Hype Cycle for 3D Printing, 2017* and *Hype Cycle for Emerging Technologies, 2017* (technical maturity curve method); the US National Audit Office uses the technology maturity evaluation method, which evaluates the national defense project, and the US DoD uses the technology maturity evaluation method as an important evaluation tool and control method for the weapon

equipment acquisition process (technical maturity evaluation method); the US National Research Council used the "quality function development method" for NASA's 14 Evaluation and prioritization of roadmaps in the technical field (quality function development method); Japan used the "scenario analysis method" to conduct the tenth technical foresight, and Korea used the "scenario analysis method" to predict the ten emerging technologies for solving social problems in 2016 (scenario analysis); the German Federal Ministry of Education and Research used the "social trend focus method" to carry out the second technical foresight.

Table 6. Analysis of typical methods for evaluation and prediction of disruptive techniques in foreign countries.

No.	Method	Qualitative/quantitative	Input	Output	Applicability	Technical tools
1	Technology Maturity Curve	Quantitative	Media coverage, maturity level of technical performance	Assessment of the current state of technology development	Mainly used to evaluate the visibility and development maturity of technology	Expert consultation and evaluation
2	Technology maturity evaluation	Quantitative	Technical maturity evaluation criteria, technical performance maturity level	The degree of development of the technology is determined	Used to evaluate the extent to which the identified key technologies are mature	Expert consultation and evaluation
3	Quality function expansion	Qualitative and quantitative combination	Matrix, evaluation criteria and weights	Priority of different technology options	Mainly used to establish and evaluate the mapping between technology and demand and give higher weight to technologies that meet important needs.	Expert house、Expert scoring
4	Scenario analysis	Qualitative	Key impact factors for future scenarios	Detailed description of future scenarios	Evaluate and forecast scenarios with multiple development possibilities	Expert consultation and evaluation
5	Social trend focus	Qualitative	Social trends	Opportunity challenge and technology field	Medium- and long-term technical forecast	Expert consultation and evaluation

In addition, according to different research perspectives, the research on foreign disruptive technology can be approximately divided into identification of technological fields/social trends (common methods include technical definition, questionnaire survey, literature measurement, scenario analysis), determination of technical direction/technical challenges (commonly used methods include research, interviews, standard screening, quantitative analysis,), and research on a specific technology (common methods include expert discussion, technical supplement, quantitative evaluation, road map, scene simulation). These aspects are not elaborated in this paper.

3 Summary of domestic disruptive technology and research methods

The domestic research on disruptive technologies is primarily divided into two categories.

The first category is the research conducted by experts and scholars at the academic level. In recent years, many experts and scholars in China have explored the identification, evaluation, and prediction of disruptive

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technologies, by primarily attempting to use scientific methods to predict the disruptive technology. Although, in general, most of the work is theoretically strong and relatively more scientific, the research on disruptive technology still focuses on the judgment of individual technologies. Moreover, the forecasting workload is large and there still exists certain challenges in the identification of large-scale technologies at the national level. In addition, owing to the existence of certain professional barriers in various industries, further verification is required to identify if the relevant methods are universal for different industries.

The second category is the disruptive technology forecasting activities conducted by professional institutions at the national level. The main research methods are expert interviews and questionnaire surveys. The comprehension of theory is relatively weak as the focus is on the operability, universality, and ease of use of research methods. The representative works include the disruptive technology forecast in the "National 13th Five-Year Technology Forecast" launched by the Ministry of Science and Technology in 2013, "China's Engineering, Science, and Technology Development Strategy Research 2035" launched by the Chinese Academy of Engineering in 2015, and the "Research on Major disruptive Technology Predictions Leading to Industrial Change" launched by the Academy of Engineering in 2016.

The Ministry of Science and Technology added the relevant content on disruptive technology forecasting and evaluation in the "13th Five-Year Technology Forecast" launched in 2013. The aim of the Ministry of Science and Technology's "13th Five-Year Technology Forecast" is to "Clarify the current status of key technologies in the current areas, predict the key technologies that will constrain economic and social development in the next five to ten years, and propose national key technology choices; focus on following the laws of technological development, common key technologies, and disruptive technologies." While predicting a disruptive technology, the Ministry of Science and Technology did not utilize the "technical bottom-technical forecast" approach that was used in the "national key technology" forecasting process. Generally, the choice of technology includes "three stages" to advance the basic procedures; however, considering the disruptive technical concepts of connotation and selection, more than ten disruptive technologies were selected by the recommendation of experts. This work was the first exploration of the disruptive technology prediction at the national level and provides a methodological reference for other institutions to conduct disruptive technology prediction.

In "China's Engineering, Science, and Technology Development Strategy Research 2035," the Chinese Academy of Engineering had set up a technical foresight group to support the key areas of engineering technology and the primary technology choices for 2035, including disruptive technologies and cutting-edge technology predictions. In the research, the technology foreseeing group comprehensively used various methods such as literature measurement, patent analysis, Delphi method, and technology maturity to conduct demand analysis while performing technical foresight, and insisted on combining technology prediction with social and economic development. A series of research results, such as "Overview of Domestic and Foreign Technology Foresight Activities," "Technology Foresight Area Division," and "Technology Foresight Questionnaire Template" have provided a good reference for domestic institutions to carry out disruptive technical selection [3].

In the process of conducting the "Research on Major Disruptive Technology Predictions Leading to Industrial Change," the Chinese Academy of Engineering utilized two rounds of questionnaires, starting with the disruptive technical connotation of industrial transformation and the establishment of an index evaluation system for disruptive technologies that triggered industrial change. Based on the wisdom of academicians and experts, 165 "reserve techniques" were selected from the 313 technologies of the "alternative technology list," and 26 "preparatory technologies" were selected from the 165 "reserve technologies." This project fully absorbs and implements the research ideas and results obtained from the "13th Five-Year Technology Forecast" and "China's Engineering, Science, and Technology Development Strategy Research 2035", such as the use of the Ministry of Science and Technology in the "National Key Technologies." In the basic procedure of the three-stage advancement of "Technology Mapping – Technology Forecasting – Technology Selection" adopted in the forecasting process, the technology in the initial "Disruptive Technology Alternative List" of the project also refers to and includes the technology considered in the "13th Five-Year Plan." In the predictions and the "China's Engineering, Science, and Technology Development Strategy 2035" study, 1149 items and 807 technologies were investigated [4].

The above work is a preliminary exploration of the disruptive technology prediction and evaluation techniques by relevant domestic institutions. It provides a research method for other institutions to perform disruptive technology prediction at a later period; however, it also exposes many aspects that require improvements, which primarily include the following shortcomings: the research method is still based on the Delphi method, it is highly

dependent on the experience of experts in various fields, it demonstrates an unavailability of mature and reliable measurement models and other methods, and it is considerably subjective. Further, the number and coverage of experts participating in the questionnaire still demonstrate insufficient reference to the viewpoints of the industry; thus, it is easy to overlook a disruptive technology in the industrial breeding stage. Thus, the research basically adheres to the "acknowledged technical views" of thinking and lacks a systematic thinking process that can adapt to the development trend of unknown disruptive technologies.

4 Suggestions for promoting scientific development and rapid prototyping of disruptive technology research in China

To promote scientific development and rapid prototyping of the disruptive technological research in China, the following suggestions are proposed:

First, focus on superior resources to set up professional think tanks and methods for long-term tracking and research on disruptive technologies. It is recommended to rely on the Chinese Academy of Sciences and the Academy of Engineering to establish several disruptive technology research think tanks, provide stable financial support, track the development of these technologies and the process of industrialization, and publish the results of the research. It is recommended that the above-mentioned think tanks aim to be at the forefront of the disruptive technology development process of the world, focus on the major strategic tasks of the country, build disruptive technology identification methods and research theories, and also focus on the original disruptive technologies. It is necessary to accurately target areas such as information networks, biotechnology, and other technologies that have revolutionized the prospects of major industries, and to study the intercrossing and penetration effects of technologies in various fields and industries.

Second, establish a scientific technology assessment system to support enterprises to cultivate and develop disruptive technologies. It is suggested that the above-mentioned think tanks should explore and establish an unconventional technology evaluation system with non-consensus indicators and gradually establish and improve an evaluation mechanism that conforms to the characteristics and laws of disruptive technology development. On this basis, the organization experts can use the technology evaluation system to evaluate potential disruptive technologies and select a group of potential disruptive technologies for project demonstration. Concurrently, it is recommended that the Ministry of Science and Technology should establish special funds for disruptive technology in the major national science and technology projects, support large-scale enterprises leading in innovation to focus on the medium- and long-term markets, and develop disruptive technologies that have been successfully demonstrated.

Third, the introduction of venture capital can increase the fiscal and tax incentives and activate the technological industrialization drive of the enterprises. It is recommended that provincial and municipal governments should set up scientific and technological consulting and service agencies to provide investors with advice and services and reduce the amount of venture capital obtained by enterprises. Provincial and municipal governments can also explore the establishment of their own venture capital foundation. Further, they can also establish and improve the science and technology financial service system, explore new financing support models for small- and medium-sized enterprises such as "investment and loan linkage," and dredge financial access to small- and medium-sized innovative enterprises. Enterprises are required to establish the actual application plan or technology roadmap that best satisfies the disruptive technology application scenario, clarify the specific implementation process of the disruptive technology industrialization, avoid blind follow-up, and accelerate technology conversion.

Fourth, to effectively link the various elements of the industry, academia, and research, and to work together to confront the bottleneck of industrialization, it is recommended to conduct research on high-end think tanks, research institutes, universities, and enterprises performing disruptive technological research and establish regular exchange seminars to share the research results. At the same time, it is recommended that the provincial government should organize the construction of an industry-university-research integrated system, establish a multi-group innovation alliance or research group composed of scientific research institutions, universities, and enterprises, link up the upstream and downstream of information and the factors of production, and direct education and research of the disruptive technology. The bottleneck of disruptive technology is industrialization. Scientific research institutions and universities can provide a certain proportion of funds and enterprises to promote disruptive technology industrialization. Enterprises can also provide disruptive technological research and development funds to universities and scientific research institutions. Subsequently, enterprises can promptly link

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the disruptive technological innovation requirements into production.

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