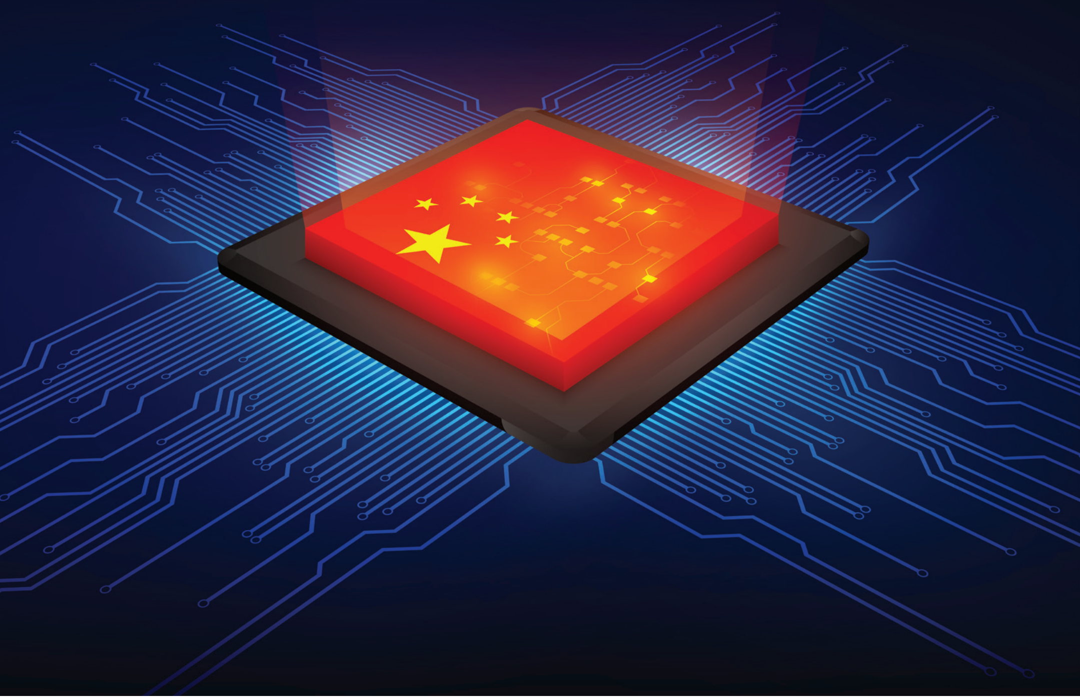
NIU
NATIONAL INTELLIGENCE UNIVERSITY
Ann Caracristi Institute For Intelligence Research

RESEARCH FELLOWSHIP



RESEARCH MONOGRAPH

China's Artificial Intelligence Ecosystem

Maj Richard Uber, PhD, USAF
National Intelligence University

China's Artificial Intelligence Ecosystem

Maj Richard Uber, PhD, USAF

NATIONAL INTELLIGENCE UNIVERSITY

ISBN: 978-1-932946-08-6

Information Cutoff Date: December 31, 2020

Abstract

Artificial intelligence (AI) is one of many emerging technologies at the heart of economic and military competition between the United States and the People's Republic of China. However, the structural differences between the two nations create a barrier to understanding the strengths and weaknesses of one another's systems. This NIU Research Monograph provides an overview of China's AI industry ecosystem from policies to execution, paying specific attention to key government ministries, private companies, and professional associations that drive industrial growth. After an introduction to the major features of the industry, a summary of AI industry assessments compares the U.S. and Chinese AI ecosystems directly and highlights key strengths and weaknesses inherent in the Chinese model.

Research Questions

The aim of this work is to take a broad look at China's AI ecosystem. Driving the investigation are the following research questions:

1. How is China challenging U.S. primacy in AI, what are China's prospects for success, and what are the implications for the United States?
2. How do Beijing's AI growth strategy and AI ecosystem components position China to achieve its AI ambitions to lead the world in AI by 2030?
3. How is China likely to apply the lessons from its COVID-19 experience to strengthen its AI infrastructure?
4. What are China's strengths and weaknesses relative to U.S. leadership in AI, and what are the implications for U.S. competitiveness?

To address these questions fully, this research is grounded in both primary and secondary sources from China and the United States. To the greatest extent possible, Chinese language original source documents are referenced to fully flesh out how the goal for, and views on, AI of the Chinese Communist Party (CCP) have evolved and adapted to create the current ecosystem.

Key Findings

China's AI ecosystem is a strategic priority of the CCP. The vice premier oversees implementation of strategic AI plans, and party guidance permeates through academia and private industry.

The CCP frames AI as a game-changing technology at the heart of its future digital economy. This strong national rhetoric and drive to be the world's leader motivate businesses and private citizens to adopt and implement AI tools at much higher rates than observed in other countries.

Two key ministries lead the government's plans for AI development. The Ministry of Science and Technology (MOST) coordinates China's AI development strategies and academic research. The Ministry of Industry and Information Technology (MIIT), through its network of think tanks and industry alliances, coordinates fielding and testing of AI applications, as was seen in China's response to COVID-19.

Scientific professional associations (SPAs) in China are closely tied to the CCP and work to implement national strategies by integrating government, industry, and academia. SPAs and industry alliances are key players in the AI ecosystem.

The CCP is increasingly leveraging private companies to drive innovation. These efforts are visible in both the naming of a "National Team" for AI and in plans for "New Infrastructure." AI, as a component of China's "New Infrastructure," will drive increased government and private sector investments in foundational capacity like data centers, cloud computing, and wireless communications.

COVID-19 pressure-tested China's AI ecosystem, demonstrating the central government's ability to rapidly unify the industry for a common purpose. Rapid response from both large and small AI businesses and researchers yielded a wide range of technical solutions for prevention and control. One of the most notable achievements was the nationwide rollout of health code apps in less than 30 days.

Robots and autonomous vehicles, deployed in response to COVID-19, accelerated real-world fielding of new technology, as seen with self-driving taxis in Beijing.

China's AI industry ranks second to the U.S. sector overall and leads in some categories, including adoption rates, data, robot installations, journal publications, and supercomputers.

Chinese strategic plans focus on metrics, and industries often meet stated goals. However, metric-based goals for AI might be driving quantity over quality.

Many of China's most talented AI researchers pursue graduate school and careers in the United States. However, future competition for talent will become more intense as Chinese domestic education and economic opportunities continue to grow.

International competition depends on a strong network of likeminded nations with whom to collaborate and cooperate. Building America's network of international partners will strengthen supply chains for both critical components like semiconductors and talent to stimulate future innovations. These partnerships could also yield lower cost AI products, enhancing market competitiveness against Chinese technologies.

Contents

Preface

This work represents the capstone research product of a 15-month Research Fellowship at the National Intelligence University's Ann Caracristi Institute for Intelligence Research (CIIR). Some content was previously published by the National Intelligence Press but is included here for completeness; for example, please see the author's *Research Note*, "China's COVID-19 Response Battle Tested Its AI Ecosystem" [*link*]. This research was made possible through tireless support from the CIIR staff, faculty mentors, 2019-20 CIIR Fellows cohort, and numerous conversations with practitioners inside the Intelligence Community, Department of Defense, think tanks, and academia.

The Chinese Communist Party (CCP) 2017 *Next Generation Artificial Intelligence Development Plan* called for China to become the world leader in artificial intelligence (AI) by 2030. This goal was strongly contested by the United States in 2019 when President Trump signed the *Executive Order on Maintaining American Leadership in Artificial Intelligence*. Although economic competition between U.S. and Chinese technology firms had been heating up for several years, 2019 marked the start of a new style of competition: one that pits two economic dynamos and their national industrial capacities against one another.

In 2017, the U.S. National Security Strategy made only one passing reference to "Great Power Competition."[1] However, by 2018 the term was a prominent theme in the National Military Strategy.[2] Great power competition is not constrained to national defense and plays an important role in national policies on trade, science, and education. Emerging technology and technological competition are also commonly discussed through this lens.

In August 2020, Acting Under Secretary of Defense for Research and Engineering Michael Kratsios said that "maintaining American leadership in emerging technologies," like AI, is "absolutely critical for our nation's national security, for our economic growth, and for the American worker."[3] Echoing this point only weeks later, Eric Schmidt, chair of the National Security Commission on Artificial Intelligence, summarized the opinion of the commission that "holding a global leadership position in emerging technology is both an economic and national security imperative."[4]

Competing as a great power depends upon not only the United States continuing to invest and grow, but also understanding how competitors are building and growing their capacity. China has built a vast and growing science and technology innovation ecosystem over the past 20 years, which it has expanded in recent years through national strategies, including those focused on AI. Spurred by the national goal to become the world leader in AI, Chinese businesses and people have flocked to AI applications, adopting new technologies at significantly higher rates than in the United States and European Union nations.

In the context of traditional instruments of national power, AI plays a supporting role in aspects of diplomacy, information, military, and economic strength. China's AI strategy is hyper-focused on the economic aspects of AI's potential, but one must not ignore applications in other domains.

Diplomacy: Diplomats might use AI to develop playbooks and lines of effort for executing national strategy. AI has the potential to assess complex decision spaces, providing game theoretic approaches and alternate courses of action. However, a more pressing area where AI intersects with diplomacy is in developing international standards and AI ethics. Currently, several nations and industry groups have established ethical frameworks, and there is an appetite for internationally accepted norms. As the world's two largest AI producers, the United States and China should both play a role in setting standards. If standard setting is a one-sided affair, competitors may be unfairly set back, which could lead to damaging disengagement.

Information: AI can assist with fusing multiple streams of information from news, social media, and other sources and sensors to provide enhanced situational awareness for decisionmaking. Advanced algorithms assist in automating cyberattacks, spreading propaganda, and creating social media bots to amplify preferred messaging. On the defensive end of information, AI-enhanced cybersecurity is increasingly common for detecting and protecting against both human and automated intrusions.

Military: Command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) requirements are pushing militaries to make sense of increasingly data-dense and complex environments. AI is well-suited to assist with sense-making and decisionmaking under these conditions. Other military applications of AI include autonomous military vehicles and networked anti-access area denial capabilities. Currently, most advanced nations agree that AI advancements require renewed discussion of international norms regarding the use of lethal autonomous weapon systems (LAWS).

Economy: Gartner, a leading research and advisory firm, projects that AI "will create $2.9 trillion in business value and 6.2 billion hours of worker productivity" in 2021.[5] The upward growth of the AI industry is expected to continue as more businesses and products come online in the next decade. The economic opportunities for AI integration are already driving increased competition among large nations.

This work takes a holistic look at China's AI ecosystem: first, by providing an overview of national strategies for AI and innovation; second, by describing each aspect of the ecosystem in detail; third, by analyzing the CCP's response to COVID-19 and how those measures elucidate China's AI ecosystem; and fourth, by providing a summary of recent assessments of national AI industries and a strength, weakness, opportunity, and threat (SWOT) analysis of U.S.-China AI competition.

China's AI Growth Strategy

The People's Republic of China (PRC, China) has enjoyed rapid economic growth over the past two decades. As a result, leaders in the Chinese Communist Party (CCP) have become accustomed to large budgets and public support. The large budgets allow the CCP to invest heavily in modernization projects, infrastructure, and social welfare. In 2006, China identified reform and modernization of its science and technology (S&T) infrastructure as a requirement for continued growth and prosperity. S&T continues to be a priority today as the country turns the corner toward a digital and intelligent economy. Chief government mechanisms for funding S&T innovation in China are the National Natural Science Fund of China (NSF-C), National Key R&D Programs, National S&T Megaprojects, Guiding Funds, and various talent programs.[6]

Artificial intelligence (AI) is just one of many emerging technologies in which China is investing. AI has attracted a lot of attention, however, because many of its applications are visible today. Small-scale, proof-of-concept demonstrations stimulate the imaginations of scientists, engineers, philosophers, and futurists, driving debates about AI-driven utopias and dystopias to come. Nevertheless, tangible economic and security benefits of AI are within reach, and gaining an early lead in the field could provide lasting strategic advantages in the years to come. Although the United States has historically led in AI research, development, and applications, China's 2017 announcement to take the lead in AI by 2030 is driving renewed competition. From China's perspective, AI is a cornerstone enabling technology for building a prosperous nation. Beijing's investment shows it views large-scale implementation of AI as a core national interest that will continue growing China's economy and sustain its expanding middle class by addressing social problems and improving industrial efficiency.

To address the research questions of how China is positioning itself as a global leader in AI and how Beijing aspires to challenge U.S. primacy in the field, this section of the report provides an overview of China's national strategy documents. Information is presented as a chronological overview of relevant policies beginning with S&T development and modernization, then focusing on AI development (see Table 1) and future plans. This organization provides a better understanding of the growth trajectory of China's AI industry. Over the course of 15 years, China's S&T development efforts demonstrate the CCP's clear focus on developing domestic capabilities. Increasingly, private enterprises are becoming more integral to China's national strategies as advisors and partners to the party and the government. These national plans are signposts for AI innovators, the first step in establishing China as a recognized player in the international field. To reach its stated national goal of overtaking U.S. leadership in AI, "China uses a multifaceted approach…that fuses both legal and illegal acquisition of foreign technologies, reverse engineering, and indigenous production."[7]

Foundational Plans

The current Chinese framework for stimulating high-tech innovation was established with the National Medium- and Long-term Program for Science and Technology Development (2006-20). This forward-looking strategic document identified the need to engage the private sector if China's aspirations were to become reality and acknowledged the need to "place the strengthening of indigenous innovative capability at the core of economic restructuring, growth model change, and national competitiveness enhancement."[8] Embedded in the program was the guiding language for establishing a "National Innovation System" by focusing on four key areas:

1. Enterprises becoming main players in technological innovation.
2. Establishing a modern research institute system.
3. Reforming the S&T management system.
4. Constructing a national innovation system with Chinese characteristics.[9]

The program, covering the years 2006-20, did not address AI directly but did discuss the need for advanced computing, intelligent robotics, natural language processing, and other technologies that are either directly or tangentially related to AI. The four key areas established a structure into which AI innovation has been integrated.

Key area 1 recognized the need for public-private partnerships to stimulate innovation. The desire to have private enterprises as drivers for innovation has fostered government funding and a host of grant programs to incentivize S&T research and development (R&D), as well as development of new applications to address commercial interests. The defense sector has also fallen in step by looking for opportunities to capitalize on S&T expertise in the private sector to support military and defense projects. Today, these programs generally fall under the concept of military-civil fusion (MCF) or civil-military integration.

Key areas 2-4 mainly addressed the national administration of scientific endeavors. Looking back from the vantage of 2020, the program's sustained long-term focus on R&D and S&T innovation has paid substantial dividends. New plans and programs for artificial intelligence, an inherently multidisciplinary science, integrate experts, resources, and capital.

The Medium- and Long-term Program spanned three five-year planning periods for the CCP. The 11th Five-Year Plan (2006-10) emphasized increasing international collaboration on key research projects,[10] apparently an admission that the current state of Chinese S&T infrastructure was not on par with advanced nations at that time. Calls to collaborate with international researchers eventually developed into international cooperation. During the 12th Five-Year Plan (2011-15), the central government published the 12th Five-Year Plan Thoughts and Objectives for International Science and Technology Cooperation (2011), which clarified goals to innovate through openness, achieve win-win outcomes through cooperation, stimulate national S&T development through international S&T cooperation, and expand the international influence of Chinese S&T. Furthermore, the government called for cultivating a cadre of international talents who would help quickly raise China's domestic innovation capacity.[11]

When Made in China 2025 was published in 2015, it symbolized a new tone for national strategies. Chinese President Xi Jinping's ideas of the Chinese Dream and National Rejuvenation were reflected in this plan, which aspired for China to "no longer be a mere consumer of the world's most advanced technology, but active in creating, leading, and defining international technological standards," with the goal "to free itself from dependency on foreign technology and develop indigenous, high-tech capabilities that satisfy its lucrative domestic market and serve and strengthen its military."[12] Made in China 2025 laid the foundation for all subsequent S&T-focused plans that China has announced. Consult Table 1 for recent plans related to AI.

Table 1: Summary of PRC Strategic Plans for AI and Innovation

Year	Plan	Key Elements
2015	Made in China 2025	Identifies robotics and next-generation IT as national key industries. Calls for increased R&D spending, patent applications, and digital applications for design and control for manufacturing. Addresses technology areas including autonomous robots, partially autonomous vehicles, and advanced computers.
2016	13th Five-Year Science and Technology Innovation Plan	Specifies China's overarching objective to be listed among the top 15 most innovative nations. Sets targets for growing research expenditures, increasing patents, and enhancing human capital.
2017	A Next Generation Artificial Intelligence Development Plan	Calls for China to 1) reach parity in AI with world leaders by 2020; 2) take the lead in some areas of AI applications by 2025; and 3) become a world leader across all aspects of AI (theory, technology, and applications) and a major world center for AI innovation by 2030.
2017	Three-Year Action Plan for Promoting Development of a New Generation Artificial Intelligence Industry (2018–20)	Provides general framework for incorporating AI into various facets of industry. Lists several key applications and foundational technologies, including networked vehicles, intelligent robots, intelligent unmanned aerial vehicles, video and image processing, medical diagnostic tools, and natural language processing.
2019	Guidance on National New Generation Artificial Intelligence Open Innovation Platform Construction Work	Formalizes National AI Team initiated in 2017 and expands roster to 15 Chinese companies serving as leaders and key integrators for open development in their application areas.
2019	2019 Defense White Paper: "China's National Defense in the New Era"	States that cutting-edge technologies—like AI, quantum information, big data, cloud computing, and internet of things (IoT)—have accelerating application in the military domains. Calls out military-civil fusion as a key component of force modernization, including leapfrog development in key areas and building a powerful strategic support force.
2020	New Infrastructure White Paper	Lays foundation for public-private investments in high-tech infrastructure to enable future economic growth. Expects formal government strategy documents to follow 14th Five-Year Plan (2021-25).

Sources: Katherine Koleski, The 13th Five-Year Plan, U.S.-China Economic and Security Review Commission, Staff Research Report, February 14, 2017, 11-12, https://www.uscc.gov/sites/default/files/Research/The%2013th%20Five-Year%20Plan_Final_2.14.17_Updated%20(002).pdf; 十三五 国家科技创新规划 [13th Five-Year Science and Technology Innovation Plan], People's Republic of China, July 28, 2016, http://www.gov.cn/gongbao/content/2016/content_5103134.htm; Paul Triolo, Elsa Kania, and Graham Webster, "Translation: Chinese Government Outlines AI Ambitions Through 2020," New America, January 26, 2018, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/translation-chinese-government-outlines-ai-ambitions-through-2020/; State Council, Defense White Paper: "China's National Defense in the New Era" [in Chinese], People's Republic of China, 2019, http://www.81.cn/jmywyl/2019-07/24/content_9567323.htm.

Current Plans

In 2016, the CCP published a companion document to the 13th Five-Year Plan, the 13th Five-Year Science and Technology Innovation Plan (STIP), as a blueprint to stimulate innovation.[13] The document listed guiding principles which clarified China's goals of taking the lead in global S&T advancement and developing talent. The STIP also introduced the term "innovation ecosystem" [14] to describe a key component for creating a highly efficient and coordinated national innovation system, specifically calling out supporting factors for innovation including intellectual property protections, governmental policies, and entrepreneurship. The STIP set a five-year goal to move by 2020 from #18 to #15 on an unspecified Innovation Index.[15] According to the updated Global Innovation Index, China reached #14 in 2019 (with Hong Kong ranking #13).[16] By this measure, it appears that China has successfully stimulated domestic innovation and exceeded its goals. The STIP also set a goal to double Patent Cooperation Treaty patent applications by 2020. According to the World International Property Organization, China is on track to at least come close in 2020. The national output was 53,990 patent applications in 2019, up by more than 10 percent from 2018.[17] If similar growth is seen in 2020, China could meet or exceed its target of 61,000 applications. The STIP also listed AI—along with quantum information and mobile internet—as a disruptive technology that the government should focus on expanding.

Since publishing China's 13th Five-Year Plan (2016-20) and the associated STIP, the CCP has clarified its AI goals. Subsequent strategic documents have focused on developing a world-class AI ecosystem. In 2017, the State Council issued the cornerstone Next Generation Artificial Intelligence Development Plan (AIDP),[18] announcing strategic goals to make China a global leader in AI. These goals have been summarized by MOST in the following three steps:

> Step 1. By 2020: Overall AI technology and application reach globally advanced level. AI industry becomes new economic growth point. AI technological application becomes new approach to improving people's livelihood to support our goal in becoming an innovation-driven country and building a moderately prosperous society in all respects.
>
> Step 2. By 2025: AI basic theory makes breakthroughs. AI technology and application reach globally advanced level. AI becomes a major driving force for industrial upgrade and economic restructuring. Building an intelligence society makes progress.
>
> Step 3. By 2030: AI theory, technology, and application reach globally advanced levels. China becomes global AI innovation center. Intelligence economy and society make marked progress, laying a solid foundation for becoming an innovation-driven and economically powerful country.[19]

Looking more closely at the goals laid out in the AIDP, Huw Roberts et al. separated the major milestones into three categories: geopolitical, fiscal, legal and ethical, as shown in Figure 1.

Also in 2017, China's S&T Innovation 2030 list of major projects included AI 2.0 alongside smart electric grid, intelligent robotics, smart manufacturing, big data, integrated information networks, and national cyber security.[20] Adding more specificity, the New Generation AI Megaprojects announced in 2018 included pursuits focusing on foundational requirements for AI breakthroughs and awarded as much as 870 million RMB ($130 million) in funding for these projects, outlined in Table 2.[21] China has historically

Figure 1. Visualizing China's Artificial Intelligence Development Plan

	By 2020	By 2025	By 2030
Geopolitical	Maintain competitiveness with other major powers and optimise its AI development environment	Have achieved a major breakthrough in basic AI theory and to be world-leading in certain applications	Establish China as the world's innovation centre for AI by 2030
Fiscal	AI industry worth more than 150 billion yuan	Increase the worth of its core AI industry to over 400 billion yuan	Growth in the core AI industry is expected to double again and be valued at 1 trillion yuan
Legal and ethical	Establish initial ethical norms, policies and regulations for key areas of AI	Expand upon, and codify in law, ethical standards for AI	Further upgrades in the laws and standards to be expected, to deal with newly emerging challenges

Source: Key points used in preparing this figure are from Huw Roberts et al., "The Chinese Approach to Artificial Intelligence: An Analysis of Policy and Regulation," Social Science Research Network, September 1, 2019, 4, https://papers.ssrn.com/sol3/papers.cfm@abstract_id=3469784.

Table 2: Research Topics for Next Generation AI Megaprojects, 2018

Subject area	Topics
Fundamental theories of new generation AI	1. New generation neural network models 2. Adaptive sensing for open environments 3. Cross-media causal interference 4. Game theory-based decisionmaking under scenarios of incomplete information 5. Emerging mechanisms and calculation methods of collective intelligence 6. Man-in-the-loop hybrid enhanced intelligence 7. Methods for human-machine integrated control in complex manufacturing environments
Key generic technologies serving major needs	1. Knowledge learning and compute engines in generalizable fields 2. Cross-media analytical reasoning technology systems 3. Scene active sensing technologies during cognitive tasks 4. Research on stimulation and convergence of collective intelligence for group software development 5. Research on software and hardware technologies for human-machine coordination 6. Autonomous intelligent precision perception and operation in unmanned systems 7. Autonomous smart agents' dexterous and precise operation and learning
Smart chips and systems	1. New types of sensory devices and chips 2. Key standards and validation chips for neural network processors

Source: China Innovation Funding, "'2030 Megaproject'—New Generation Artificial Intelligence (2018 annual call)," http://chinainnovationfunding.eu/project/2030-megaproject-new-generation-artificial-intelligence/.

lagged behind the United States in novel theoretical approaches, an area where developments can help propel industry growth. Generic technologies, the second category of research topics, are those that can be used across various applications. The third subject area addressed by the AI Megaprojects is microchips. State-of-the-art AI chips can support the scale and efficiency required for cutting-edge AI algorithms.[22] Coupling advanced chip designs with investment in domestic fabrication infrastructure is key to building a robust AI ecosystem and reducing supply chain dependence on the United States and its allies.

Two Chinese ministries take the lead in implementing the AIDP: the Ministry of Science and Technology (MOST), which is charged with executing the national strategy, and the Ministry of Industry and Information Technology (MIIT), which appears to be the lead on industry guidance. MOST also oversees the National Open Innovation Platforms and National New-Generation AI Development Experimental Zones. The latter include Beijing, Shanghai, Hefei, Hangzhou, Shenzhen, Tianjin, Chongqing, Chengdu, Xi'an, Jinan and the county of Deqing. Current plans are to expand to about 20 total zones by 2023 with the intention of promoting cooperation with local governments, demonstrating AI technologies, and piloting experimental policies for AI development.[23, 24]

MIIT plays a key role in connecting the private sector to the national strategy. Following the AIDP's publication, MIIT released the Three-Year Action Plan for Promoting Development of a New Generation Artificial Intelligence Industry (2018-20) in December 2017. A few months later, the MIIT released a "work plan for key projects for the development of the next generation of AI," which included the following 17 priority areas (see Appendix 1 for the complete list with sub-areas and examples):[25]

1. Intelligent connected cars
2. Intelligent service robots
3. Intelligent unmanned aerial vehicles
4. Medical imaging diagnostic support systems
5. Video image identification systems
6. Intelligent voice interaction systems
7. Intelligent language translation systems
8. Intelligent home appliance systems
9. Smart sensors
10. Neural network chips
11. Open source, open platforms
12. Key technical equipment for intelligent manufacturing
13. Repository of industry training resources
14. Standard testing and intellectual property service platform
15. Intelligent network infrastructure
16. Network security assurance systems
17. Other directions[26]

The breadth of topics promoted by government policies makes it clear that the Chinese objective is not to be the best in one specific application area, but instead to grow the larger national capacity in AI. This is similar to a *rising tide floats all boats* strategy, where government investments in AI are seen as raising the average level of knowledge and ability in the country. However, with so many small projects, it becomes difficult for the government to effectively manage and support collaborative growth and development. To address this issue, the Chinese government has started identifying private companies as New Generation AI Open Innovation Platforms, commonly referred to as the "National Team" for AI.

Between 2017 and 2018, MOST and other ministries selected five initial New Generation AI Open Innovation Platforms: Baidu for autonomous vehicles, Alibaba (Ali Cloud) for smart cities, Tencent for medical imaging, iFlyTek for smart audio, and Sensetime for smart vision. These large companies, listed in the top row of Figure 2, recommend plans for AI projects, infrastructure, and training and recruiting new talent. In these efforts, the companies frequently work with government stakeholders, including MOST, Ministry of Finance, Ministry of Education, MIIT, and the Chinese Academies of Science. Some key goals of this "National Team" are to systematically improve talent development and direct AI capital investments.[27]

Figure 2. China's National Team for AI

Red boxes added to designate those companies placed on the U.S. Commerce Department's Bureau of Industry and Security Entity List. Source: Benjamin Larsen, "Drafting China's National AI Team for Governance," New America (blog), November 18, 2019, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/drafting-chinas-national-ai-team-governance/.

In August 2019, MOST released the Work Guidelines for the Construction of New Generation Artificial Intelligence Open Innovation Platforms (国家新一代人工智能开放创新平台建设工作指引).[28] This document named ten more companies, shown in the second and third rows of Figure 2, to the "National Team" and laid out principles expected of nationally recognized AI open innovation platforms, shown in Table 3.[29] As described in MOST's Work Guidelines: "New Generation AI Open Innovation Platforms focus on key areas and segments of artificial intelligence, and act as effective magnets and clusters for AI-related technologies resources, industrial chain resources, and financing resources; they aim to contribute to more sustained R&D activities and to a wider transfer, dissemination and commercialisation of AI-related scientific achievements across all sectors of the society, including talents, teams, micro-, small and medium sized enterprises [MSMEs]."[30]

Table 3: New Generation AI Open Innovation Platforms' Founding Principles

Principle for Construction	Explanation
Application-driven	Research on basic theories, key core technologies, hardware, software, and products must be done in areas where there is major demand for application.
Enterprise-led	Enterprises are encouraged to establish open-source and collaborative platforms, sharing resources with the wider society. Leading enterprises will have the key guiding role and will assist and support the growth of MSMEs.
Market-oriented	Platforms should be operated according to market mechanisms. Host enterprises must provide funding and other support through technology licensing, transfer, and compensation.
Integration and Coordination	All actors—including local governments, industry actors, research structures, and universities—should actively participate in Open Innovation platforms.

Source: China Innovation Funding, "Work Guidelines for the Construction of New Generation Artificial Intelligence Open Innovation Platforms," People's Republic of China, http://chinainnovationfunding.eu/dt_testimonials/work-guidelines-for-the-construction-of-new-generation-artificial-intelligence-open-innovation-platforms/.

The application-driven, enterprise-led, and market-oriented principles for Open Innovation Platforms illustrate Beijing's desire to create economic growth in the AI sector. The principle of integration and coordination, on the other hand, demonstrates the true strategy behind the "National Team," which is further refined in the key tasks of providing sharable services, guiding investment and entrepreneurship, and promoting technology transfer. In these roles, the national champions have a responsibility to not just grow their own corporate profits, but also build up MSMEs in the same sector.

Increased visibility in the industry is a double-edged sword. In 2019, several of these national champions were designated by the U.S. Department of Commerce for enabling activities that go against U.S. foreign policy interests—specifically referring to human rights abuses like repression, detention, and surveillance of Muslim minorities in Xinjiang.[31] The Commerce Department added the Chinese companies outlined in red in Figure 2 to the Bureau of Industry and Security Entity List, a move that aims to prevent them from acquiring hardware, software, and technology subject to U.S. Export Administration Regulations.

Developing Plans

The term "New Infrastructure" (Chinese: 新基建 or 新型基础设施建设) was first used at the 2018 Central Economic Working Conference, China's highest-level annual meeting on the national economy.[32] In contrast with traditional infrastructure plans (e.g., roads, bridges, railroads, ports, etc.), the new infrastructure plans focus on laying the foundational framework necessary for a digital economy. One goal is to create intelligent networks and efficient data flows so the future Chinese economy will be able to capitalize on the full potential of big data and AI for decision support and process control.

China's Center for Information and Industry Development (CCID), an MIIT-administered scientific research institution, published the New Infrastructure Policy White Paper[33] in April 2020, identifying seven technology areas for the "New Infrastructure" framework:

1. Artificial Intelligence
2. Industrial Internet
3. Charging Framework for New-Energy Vehicles
4. Big Data Centers
5. 5G Infrastructure
6. Ultra-High Voltage Power Grid
7. Rail Transit

The National Development and Reform Commission of China (NDRC) emphasized several of these technologies in a subsequent press release,[34] as seen in Table 4.

Table 4: New Infrastructure Components and Areas from NDRC

Component	Communications Network Infrastructure	New Technology Infrastructure	Computational Power Infrastructure
Representative Technology Areas	5G, IoT, Industrial Internet, Satellite Internet	Artificial Intelligence, Cloud Computing, Blockchain	Data Centers, Intelligent Computing Centers

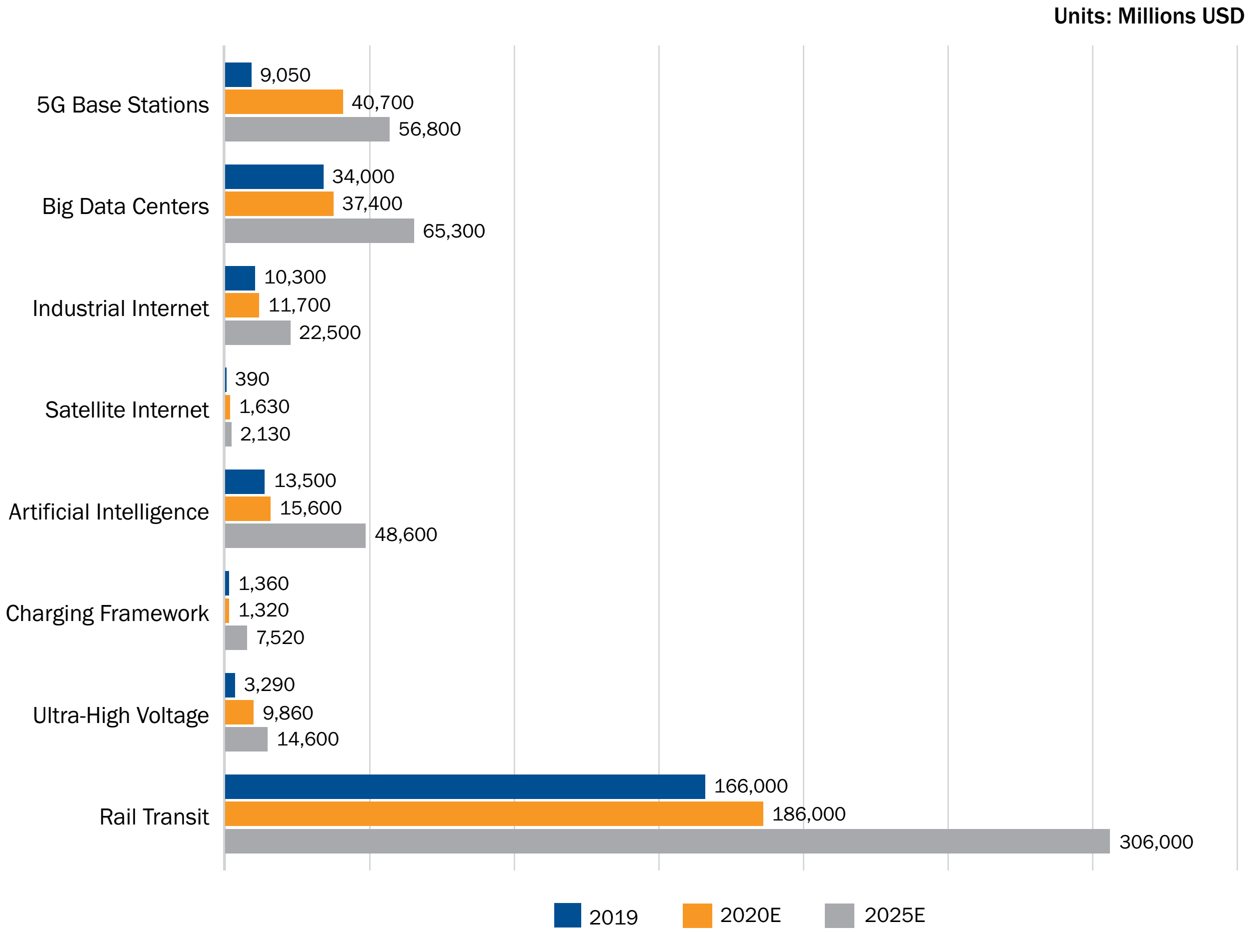
Source: National Development and Reform Commission, 国家首次官宣"新基建"范围：3大方面,7大领域, [China Makes First Official Announcement on the Scope of "New Infrastructure": 3 Major Components, 7 Main Areas], People's Republic of China, June 13, 2020, http://www.rzweiqi.com/third_1.asp?txtid=13.

Traditional infrastructure projects are common methods for boosting economies and job growth. However, China has seen during the past year how overstimulating construction projects can backfire with the creation of underpopulated "ghost cities."[35] New infrastructure projects will stimulate stronger networks and lay the foundation for more efficient future growth. Furthermore, the job opportunities created by these projects will be more technical, higher-paid positions.

As a major stakeholder in China's digital economy, Tencent has announced plans to invest $70 billion over three years.[36] While this is a large investment, especially from a private source, it represents only a fraction of the total projected national investments in the "New Infrastructure." The interplay between government and private investments is an important feature of "New Infrastructure" plans. According to the CCID white paper, "New Infrastructure" is different from traditional infrastructure in that it is driven by both private markets and the government, with the role of private investment becoming increasingly prominent.

Figure 3 shows the estimated growth in expenditures that CCID anticipates the Chinese government and private companies will invest in some of the key infrastructure projects. Note that, in 2020, expected investments total more than $300 billion.[37]

Figure 3. Expected Investments in New Infrastructure



Source: China Center for Information and Industry Development, 2020 城市新基建布局与发展白皮书 [2020 White Paper for City-level "New Infrastructure" Deployment and Development], People's Republic of China, April 2020, http://www.cbdio.com/BigData/2020-05/19/content_6156378.htm.

By June 2020, at least 619 enterprises across China were working on the key objectives of Beijing's "New Infrastructure," according to a list published by China's 5G Industry Circle. The list included 100 AI businesses—listed in Appendix 2 with English translations—plus 39 ventures related to 5G, 40 big data centers, 49 firms working on industrial Internet, 54 companies engaged in ultra-high voltage, 40 firms in the rail industry, and 297 businesses related to new energy vehicles.[38]

Not to be overlooked is how China's defense sector fits into national plans for AI development. National defense is often a consumer of AI technology, but some applications—due to their specialized nature—are developed under tight security controls. China's 2019 Defense White Paper identified AI—along with quantum information, big data, cloud computing, and IoT—as cutting-edge technologies to be rapidly integrated into the military domain.[39] Acknowledging "a prevailing trend to develop long-range precision, intelligent, stealthy or unmanned weaponry and equipment," the white paper summarizes this trend by stating "war is evolving in form towards informationized warfare, and intelligent warfare is on the horizon."[40]

In September 2020, Xi Jinping spoke to a scientists' forum to lay out his priorities for S&T acceleration in China. During the speech, Xi gave a nod to the not-yet-written 14th Five-Year Plan, saying that "development during our country's '14th Five-Year Plan' period as well as the long-term is raising ever more urgent requirements to accelerate S&T innovation."[41] While much of the speech served to motivate the scientists in the audience to continue efforts to strengthen the national research contributions, the middle of the speech addressed problems that Xi would like to solve. These major focus areas include:

1. Demand orientation of research problems.
2. Optimize S&T resources.
3. Strengthen basic research.
4. Educate and cultivate innovative talent.
5. Transform governance for S&T reform.
6. Strengthen international S&T cooperation.[42]

Table 5: Key and Core Technology Areas for S&T Innovation

Key and Core Technologies	Components (examples)
1. New-generation information technology	**Artificial intelligence**, IoT, big data, cloud computing
2. New-generation semiconductor technology	Optoelectronic chips, new-generation transistors
3. Communications equipment	5G, quantum communications
4. Biotechnology	Brain-computer interface, immunology, gene sequencing
5. Transportation, engineering machines, and manufacturing equipment	Remote-controlled machinery, robotics, advanced rail transportation, ocean engineering equipment and ships
6. Pharmaceutical manufacturing	Innovative medicines, medical instruments, diagnostic equipment, pharmaceutical services
7. New materials	Energy conserving or environmentally friendly materials, electronic information materials, biomaterials, materials for use in high-precision equipment
8. Aeronautics and astronautics	Rockets, satellites, space stations, space planes
9. New energy	Solar, nuclear, wind, biohydrogen
10. Conserving energy and the environment	Waste management, resource utilization

Source: 北京亿欧网盟科技有限公司 [Beijing Equal Ocean Technology Ltd.], 中国科学院大学经济与管理学院 [China Academy of Science Institute of University Economics and Management], 华为技术有限公司 [Huawei Technology Ltd.], 西安市硬科技产业发展服务中心 [Xi'an City Key and Core Technology Industrial Development Service Center], 2020 中国硬科技创新白皮书 [2020 China Key and Core Technology Innovation White Paper], People's Republic of China, September 2020, https://www.iyiou.com/intelligence/report745.htm.

Xi's speech foretells an upcoming S&T Innovation Strategy that will address the Chinese leader's major focus areas during the 14th Five-Year Plan period. Although Xi made no shockingly new revelations in his presentation, clearly the CCP will continue to invest in basic research, education, and innovation while revising its own S&T management system inside the government. The focus areas of demand orientation and optimization of S&T resources imply greater government input and oversight for major projects, especially domestic development of the "key and core technologies" (关键核心技术 or 硬科技) shown in Table 5. Note that AI is a principal component of China's new-generation IT plans and probably will continue to draw attention and funding from the CCP for many years to come.

Components of the AI Ecosystem

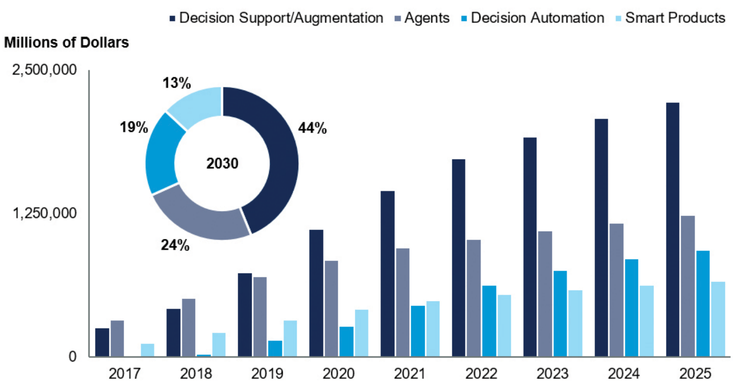
Although AI comprises a wide range of applications and technologies, an examination of national AI strategies shows that a successful AI ecosystem must include the following components: applications, industrial base, academic research, private companies, talent, and government support. Additionally, professional associations and industry alliances play a key role as integrators, connecting each of the other components. This section provides additional background information about the roles each of these components play in China's AI ecosystem. To stimulate growth and develop a world-class AI industry, China is investing across each of these components. Government, education, academia, and talent are the engines that move the entire country's ecosystem forward with strategic guidance, ground-breaking research, and the education of a well-trained workforce. Applications, industry, and private companies are driving toward realizing the economic potential of AI while at the same time presenting the most visible representation of China's AI achievements.

Applications

Applications are the lifeblood of AI. Ubiquitous sensors and fast connectivity began with mobile phones and have evolved to include smart devices of all sorts. Vast quantities of data being collected and transmitted create a fertile environment for AI applications. Networked security cameras and images shared online feed image and facial recognition algorithms. Online libraries and websites fuel text processing systems. Daily interactions with digital assistants and translation tools strengthen the output of natural language processors. AI algorithms in the wild, being used in the real world, continue to improve and adapt as they are used and applied to new and different problems. Therefore, quality applications drive increased adoption of AI technology, and increased adoption builds higher quality applications. This cycle of growth and development is critical for applications. For this reason, metrics for AI adoption can provide insight into future AI strength.

Applications are also the principal drivers for economic value. Gartner projects that AI "will create $2.9 trillion of business value and 6.2 billion hours of worker productivity globally" in 2021 alone.[43] The bulk of this value will be concentrated in applications focused on decision support, intelligent agents, decision automation, and smart products (see Figure 4). While a lot of attention is given to products, it is significant that they represent the smallest component of future AI value. To corner the future AI market, businesses should be building data tools and processes that enhance decisionmaking. Chinese strategies appear to recognize

Figure 4. Business Value Forecast for AI Applications



Source: Katie Costello, "Gartner Says AI Augmentation Will Create $2.9 Trillion of Business Value in 2021," Gartner, August 5, 2019, https://www.gartner.com/en/newsroom/press-releases/2019-08-05-gartner-says-ai-augmentation-will-create-2point9-trillion-of-business-value-in-2021.

this application area, consistently naming AI as a foundational technology. As seen above in Table 5, AI—alongside big data, IoT, and cloud computing—is a component of the new-generation information technology key and core technology areas.

Industrial Base

The industrial base of a nation provides the cornerstone manufacturing capabilities needed to create new and innovative products. The development level of a country's industrial base can be measured by proxy, looking for high-tech industries and capabilities that would not be possible except through a high-quality precision manufacturing sector. For example, sensors, communications networks, and semiconductors are the most common basic resources necessary for AI technologies. While the sensor suite may be different between planetary exploration robots and military-grade autonomous vehicles, the core technology is the same.

One benchmark national industry is the space sector. Space poses a serious barrier to entry, requiring significant autonomy and reliable long-range communications, as well as the ability to design, test, and build resilient astronautic systems. Recent Chinese advances in space, like the completion of their Beidou satellite navigation constellation and landing a rover on the dark side of the moon, illustrate a level of sophistication that rivals that of the United States. The China National Space Agency (中国国家航天局) met another key innovation milestone[44] when it launched the Tianwen 1 Mars probe onboard a Long March 5 (长征5号) rocket from the Wenchang site on Hainan Island on July 25, 2020.[45]

An interesting and often overlooked component of the AI ecosystem is the power grid. China is using AI and IoT applications to efficiently manage the country's electrical grid, as Jeffrey Ding, China lead at Oxford University's Centre for the Governance of AI, reports in his AI newsletter.[46] The "New Infrastructure" projects make clear that electrical grid hardware, management, and optimization are critical to a digital economy. Modern applications, including the ubiquitous IoT and electric vehicle charging, require on-demand electricity across a vast area. These challenges can be addressed with modern hardware and more diverse power-generation methods, but optimizing power delivery through AI may also provide significant gains. Furthermore, good data analysis of electricity consumption can aid law enforcement or industry watchdogs who may be looking for suspicious activities. A U.S. example is the discovery of marijuana-growing operations by exceptionally high electricity bills.[47] In China, a more mundane application of electrical surveillance might be to identify chronic over-consumers, an activity which could foreseeably be tied to a person's or a company's social credit rating.

As foundational technologies (e.g., semiconductor manufacturing, data centers, and sensor production) continue to flourish in China, the entire industrial base benefits. Building off its history as the world's factory and pivoting to focus on high-tech manufacturing, China has become a very capable industrial superpower; however, the AI chip, or semiconductor industry, remains a critical technological gap identified by many U.S. analysts. End-to-end processes for creating world-class microchips are exceptionally challenging, and current production involves a truly international supply chain.[48] If China can close the existing gap between its products and internationally available hardware, the domestic AI industry will be sufficiently self-reliant and buffered against U.S. and international economic pressure on supply chains. Strider CEO Greg Levesque captured this focal point of China's strategy when he wrote:

> Developing a world-class semiconductor industry is a cornerstone of the "Made in China 2025" industrial strategy and numerous technology industry plans. It serves economic development and military modernization agendas. Yet, after years of being blocked from acquiring the capability overseas, the Chinese government appears to be adapting, deploying a "by all means necessary" strategy to achieve self-sufficiency in semiconductor R&D and production.[49]

Despite its relative dependence on international supply chains for semiconductors, China has a thriving high-tech industrial base. As efforts to build up "New Infrastructure" materialize, the industrial sector will see continued rapid growth over the next decade.

Education and Academia

Academia plays an important role in the AI ecosystem. Not only are high schools and universities the primary means of producing new talent for the AI workforce, but graduate schools also house laboratories and research institutes for developing new theories, techniques, and applications. In a well-functioning ecosystem, academic institutes should regularly interact with, but not be constrained by, private industry and government sponsors.

In 2017, China rolled out its *Double First Class Program* (双一流计划) with the goal of raising its universities and undergraduate programs to a world-class level. The *Double First Class Program* is designed to replace earlier education programs like Projects 211 and 985, and it represents the current focus on educational reform, growth, and development. Beijing frequently cites lists of the worldwide top-100 universities as a measure of success. As of October 2020, China has recognized 465 undergraduate programs at 137 Chinese schools as *Double First Class* disciplines[50] and, among those schools, are the 42 *Double First Class* universities.[51] In 2019, the Ministry of Education announced a new program aimed at improving not just the top-tier schools, but raising the level of education at the lower-ranked schools as well. The *Double Ten Thousand Plan* aims to "build 10,000 national-level first-class undergraduate majors and 10,000 provincial-level first-rate undergraduate majors by 2021."[52] Table 6 lists majors related to AI, comparing the number of programs under the *Double Ten Thousand Plan* with those under the *Double First Class Plan*. By reaching out to hundreds of universities, the *Double Ten Thousand Plan* is supporting and shaping the next-generation AI workforce.

Table 6: Comparison of AI-related Majors under ***Double Ten Thousand*** and ***Double First Class*** Plans

University Majors	*Double Ten Thousand*	*Double First Class*
Computers	577	14
Electronic Information	437	13
Mechanical	407	10
Management Science and Engineering	268	6
Automation	123	9
Electrical	120	7
E-Commerce	100	0
Statistics	85	7
Instruments	56	2
Industrial Engineering	48	2
Total	**2221**	**70**

Source: 无忧文案 [Worry-free Copywriting], 继'双一流'之后，教育部又有1重大计划发布! [Ministry of Education announces another major plan to follow 'Double First Class'], Baidu Blog, April 10, 2019, https://baijiahao.baidu.com/s?id=1630345503499312627.

Since the rollout of the AIDP, schools in New-Generation AI Development Experimental Zones like Beijing have been integrating AI education into high school curricula. The first high school AI textbook, *Fundamentals of Artificial Intelligence,* was published in 2018. This textbook provides a broad overview of AI applications, including image classification, natural language processing, video processing, image generation, and strategy games like *Go*.[53] A 2019 Chinese AI report noted that "35 high schools have established intelligent S&T or AI robotics laboratories where students can undertake deep learning about human-machine interaction and AI."[54] However, because China uses a single college entrance exam nationwide for high school seniors, changes to high school curricula require significant coordination. This new high school material, in conjunction with universities rolling out new AI programs, has necessitated new AI-related questions on the National Higher Education Entrance Examination. As of 2019, students could apply to more than 70 AI programs at Chinese universities through the national entrance exam.[55]

Universities across China, and indeed across Asia, are investing heavily in their AI programs. The top 20 schools for AI in Asia, according to CSRankings.org, are shown in Table 7. The ranking factor of publication count is computed as the mean count of papers published across categories of AI, computer vision, machine learning and data mining, natural language processing, and the web and information retrieval.[56] Note that 15 of the 21 schools (two schools each tie for 17th and 20th) are located in China. All top-ranked Chinese schools, except for the two located in Hong Kong, are recognized through the *Double First Class Program*.

In addition to traditional university programs, several specialized AI institutes have been founded in partnership with the national AI champions. For example, Tencent and iFlytek partnered with Liaoning Technical University and Chongqing University of Posts and Telecommunications, respectively, to establish the Tencent Cloud School of Artificial Intelligence, the first AI school in Liaoning Province, in May 2018 and the iFlytek School of Artificial Intelligence in February 2018.[57] These enterprise partnerships not only ensure funding and support for student education and training, but also establish a direct pipeline between academic research and industry applications or postgraduate employment.

Despite recent advances in Chinese academia, a gap persists between research productivity and graduating top-quality undergraduates. According to a 2019 report from the U.S. National Academy of Sciences, China's university seniors majoring in computer science still lag behind their counterparts in the United States

Table 7: Top 20 AI Schools in Asia

# Rank	Institution	Location	First Class	Faculty
1	Tsinghua University	Beijing, China	Yes	83
2	Peking University	Beijing, China	Yes	92
3	Chinese Academy of Sciences	Beijing, China	C	42
4	Nanyang Technological University	Singapore	-	36
5	National University of Singapore	Singapore	-	31
6	Nanjing University	Nanjing, China	Yes	46
7	Fudan University	Shanghai, China	Yes	46
8	Hong Kong University of S&T	Hong Kong, China	No	27
9	Zhejiang University	Hangzhou, China	Yes	54
10	Shanghai Jiaotong University	Shanghai, China	Yes	39
11	Korea Advanced Institute of S&T	Daejeon, South Korea	-	33
12	Chinese University of Hong Kong	Hong Kong, China	No	22
13	University of Tokyo	Tokyo, Japan	-	23
14	Seoul National University	Seoul, South Korea	-	20
15	Beihang University	Beijing, China	Yes	28
16	University of S&T of China	Hefei, China	Yes	15
17	Harbin Institute of Technology	Harbin, China	Yes	19
17	Singapore Management University	Singapore	-	17
19	Renmin University of China	Beijing, China	Yes	26
20	Sun Yat-sen University	Guangzhou, China	Yes	9
20	Univ. of Electronic S&T of China	Chengdu, China	Yes	22

Schools ranked by publications from 2015 to 2020. Chinese First Class universities are indicated by "Yes," while the letter C indicates a First Class program, but not a First Class university. Sources: CSrankings, queried October 5, 2020, http://csrankings.org/#/fromyear/2015/toyear/2020/index?ai&vision&mlmining&nlp&ir&asia; 全国双一流大学名单及双一流学科名单汇总（42所一流大学+95所一流学科建设高校）[Complete list of Chinese double first class universities and double first class disciplines (42 first class universities + 95 first class discipline construction schools], 大学生必备 [College Student Necessities], August 6, 2020, https://www.dxsbb.com/news/43247.html.

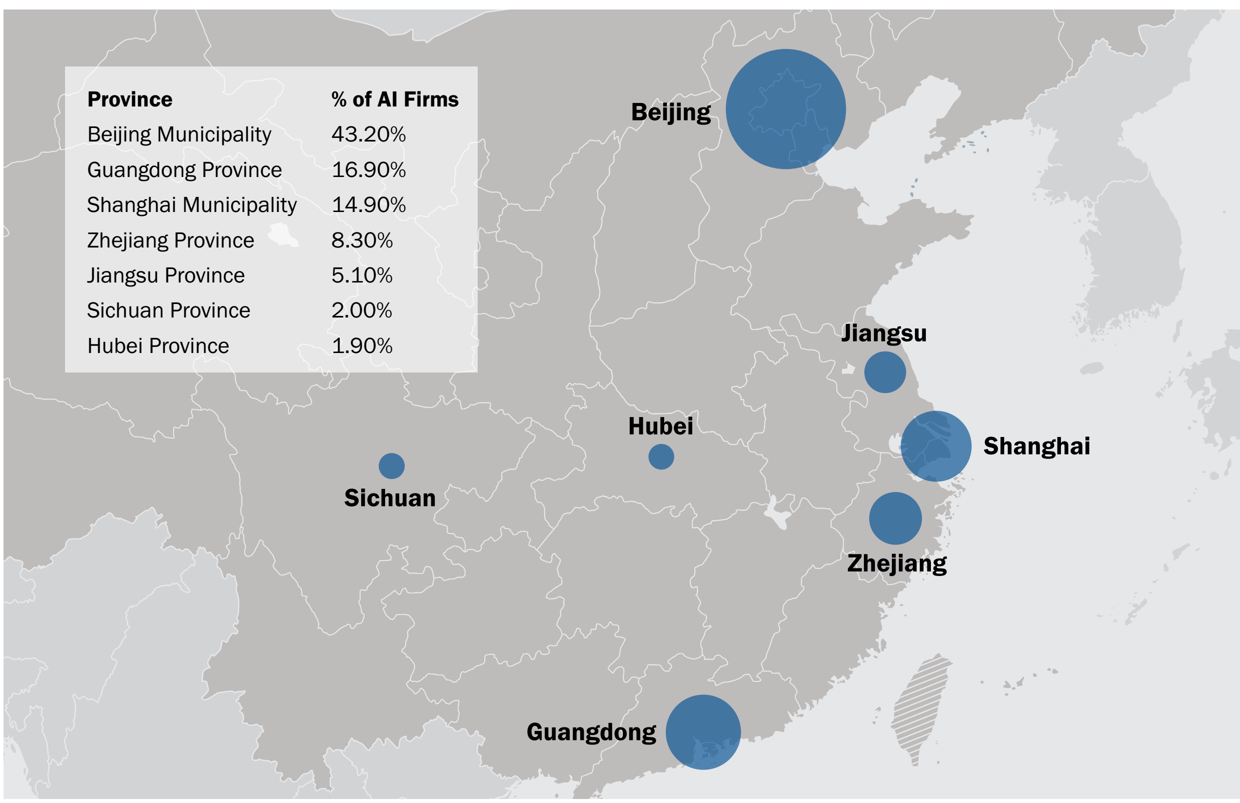
by a significant margin.[58] However, this advantage may be short-lived. The specialized AI programs for undergraduates established in recent years probably will start producing top-tier talent by 2022-23. Whether those graduates stay in China or come to the United States for graduate school and employment is still to be seen. A recent report from Georgetown University's Center for Security and Emerging Technology (CSET) concludes that "if the United States fails to adapt to an increasingly competitive global technology talent landscape, other countries may begin to draw AI talent away from American schools and employers."[59]

Another set of contributors to the academic research component are the military universities and academies. According to China's 2019 National Defense White Paper, the national defense research system is guided by the newly established Military Scientific Research Advisory Committee under the Central Military Commission of the CCP. Under the new system, the Military Academy of Science leads as the "dragon's head," military R&D institutes constitute the backbone, and service academies and R&D forces provide support for deploying military R&D power.[60] In recognition of its academic and research contributions, the National University of Defense Technology (NUDT) is named among the 36 "Type A" Double First Class Universities,[61] showing Beijing believes it to be on-par with world-class universities. As the CCP's concept of military-civil fusion matures, opportunities for collaborative work among military researchers, private industry, and universities should expand.

Private Companies

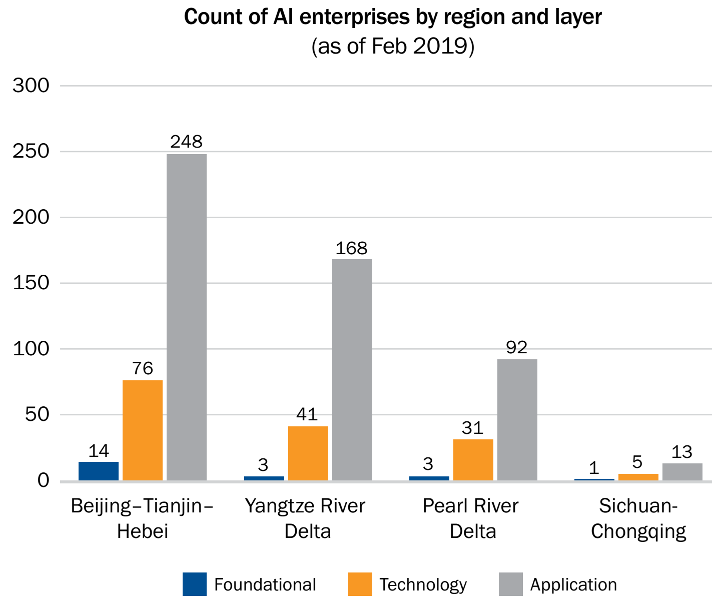
Private entrepreneurs in China are the primary driving force behind innovation. Their companies and products are also the most visible components of the AI ecosystem. The rapid and competitive nature of the AI industry is propelled by the private sector, as described in depth by Kai-Fu Lee, the CEO of Sinovation Ventures, in his book *AI Superpowers*.[62] Beyond competition for market share and profits, private companies in China are driven by government initiatives, as was seen in their response to the COVID-19 outbreak in early 2020; for example, Baidu Map applied population flow models to track the spread of the virus,

Figure 5. Regional Development Hubs Heatmap of China's AI Industry



Source: Forward Think Tank, http://www.cbdio.com/image/site2/20191009/f42853157e261f07cc5719.pdf and China Unicom laid a data-exchange foundation for epidemic prevention and control (EPC).[63] Recognizing the contributions of small companies to S&T advancement, the central government has established several pathways to support small business innovations and speed up development timelines. Under China's *New Generation AI Open Innovation Platforms*, companies that comprise the National Team are key links in the development chain.

Figure 6. Regional Development Hubs of China's AI Industry



Source: Data used in preparing this figure from Forward Think Tank, http://www.cbdio.com/image/site2/20191009/f42853157e261f07cc5719.pdf.

As of a February 2019 Chinese account at a global AI conference, there were 3,438 AI companies worldwide. Of these enterprises, the majority were based in the United States (1,446), but China had the next highest number with 745 distinct AI firms.[64] Chinese companies are primarily located in three major areas: 45.3 percent (338) are found in the Beijing–Tianjin–Hebei (京津冀) region, 28.4 percent (212) are in the Yangtze River delta (长三角 , Shanghai and surrounding area), and 16.9 percent (126) are in the Pearl River delta (珠三角, Hong Kong, Guangzhou, Shenzhen). In total, four regional development hubs—also including the Sichuan–Chongqing (川渝) region, with 19 enterprises—account for 695 (93.2 percent) of the 745 AI enterprises identified in China.[65] The geographic concentration of China's AI industry can be seen in Figure 5.

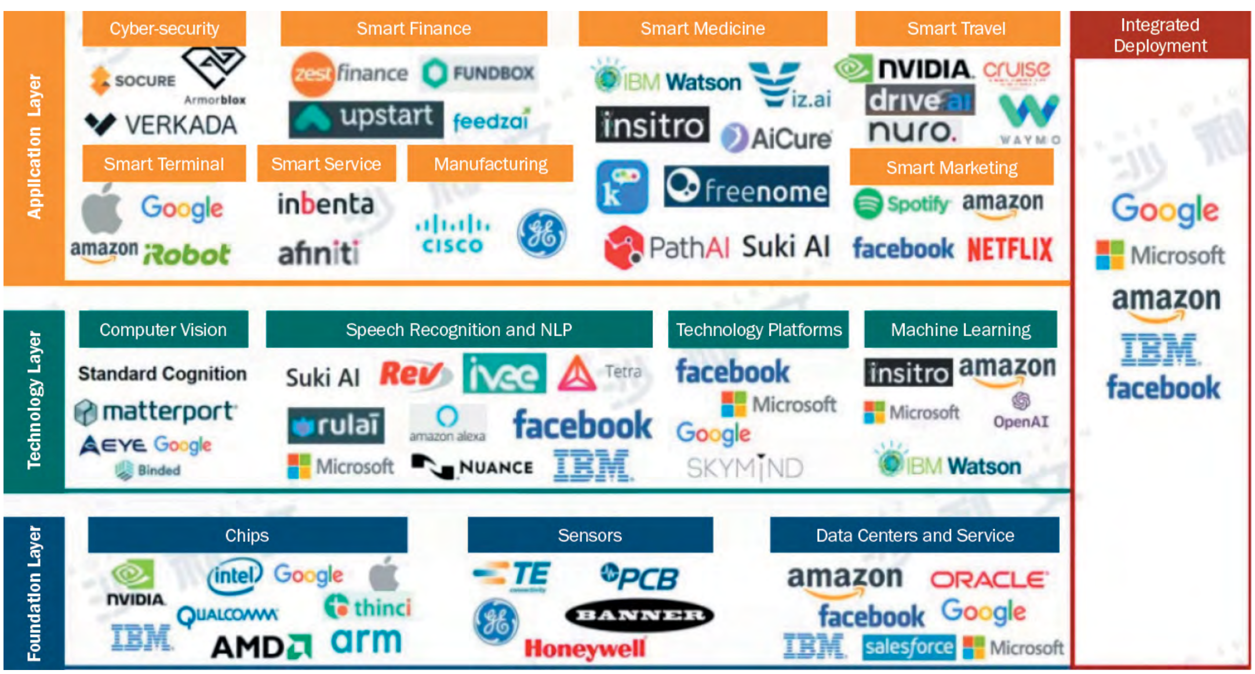
In addition to the regional concentrations of China's AI industry, MOST has named 12 cities and 1 county as New Generation AI Innovation Development Experimental Zones. The most recent additions, Guangzhou and Wuhan, were announced in September 2020. Other experimental zones are located in Beijing, Shanghai, Hefei, Hangzhou, Shenzhen, Tianjin, Jinan, Xi'an, Chengdu, Chongqing, and Deqing County in Zhejiang Province.[66]

A 2020 report from the research and consulting firm Frost and Sullivan[67] breaks the AI industry into three main layers: 1) the foundation layer, which includes chips, sensors, and data centers; 2) the technology layer, which includes computer vision, audio and natural language processing, shared platforms, and machine learning; and 3) the application layer, which includes the end-use areas of AI such as medical, finance, cybersecurity, commerce, and business operations. Large companies like Google, Microsoft, Amazon, Facebook, and IBM in the United States and Baidu, Alibaba, Tencent, and Huawei in China are considered integrators, spanning all three layers of AI development. Figure 6 illustrates the distribution within each hub, separated into foundational, technological, and application layers. Figures 7 and 8 show an overview of Chinese and U.S. companies arrayed according to the layers they support.

Figure 7. Chinese AI Companies Organized by Layer

Source: Frost & Sullivan Shanghai,一文了解中美AI产业布局：一个"行业霸主"，一个"新晋强者" [Chinese and American AI Industry Roll-out: One an "industry hegemon", one a "new powerhouse"], March 30, 2020, http://www.cbdio.com/BigData/2020-03/30/content_6155329.htm.

Figure 8. U.S. AI Companies Organized by Layer



Source: Frost & Sullivan Shanghai, 一文了解中美AI产业布局：一个"行业霸主"，一个"新晋强者" [Chinese and American AI Industry Roll-out: One an "industry hegemon", one a "new powerhouse"], March 30, 2020, http://www.cbdio.com/BigData/2020-03/30/content_6155329.htm.

Government

China's central government plays a pivotal role in its AI development and broader innovation ecosystem. In terms of implementing the CCP's national priorities for AI, two major ministries share the burden. The Ministry of Science and Technology (MOST) leans more toward academic research. For example, this ministry is responsible for the Natural Science Fund of China and for major National Projects, which include AI and intelligent robots. MOST authors many of China's AI strategic plans like the AIDP. The Ministry of Industry and Information Technology (MIIT) also conducts research through its network of professional societies, academies, and research universities. As this ministry's name might imply, it is a principal conduit for bringing technology to industry. Although MIIT oversees seven universities, shown in Table 8, those schools tend to focus more on applied research than on theoretical foundations.

Table 8: Universities Subordinate to the Ministry of Industry and Information Technology

English name	Chinese name	Website
Beihang University	北京航空航天大学	http://www.buaa.edu.cn
Beijing Institute of Technology	北京理工大学	http://www.bit.edu.cn/
Harbin Institute of Technology	哈尔滨工业大学	http://www.hit.edu.cn/
Harbin Engineering University	哈尔滨工程大学	http://www.hrbeu.edu.cn/
Northwestern Polytechnic	西北工业大学	http://www.nwpu.edu.cn/
Nanhang University	南京航空航天大学	http://www.nuaa.edu.cn/
Nanjing Institute of Technology	南京理工大学	http://www.njust.edu.cn

Source: Ministry of Industry and Information Technology (website), www.miit.gov.cn.

Aside from MOST and MIIT, which are the most prominent government ministries leading AI programs, the National Development and Reform Commission (NDRC) plays an increasingly central role in coordinating industrial plans and ensuring alignment with national strategic guidance:

> NDRC is China's macroeconomic planning body responsible for formulating and implementing strategies for national economic and social development and coordinating economic restructuring. NDRC directs industry policies, fixed-asset investment, and regional economic development.[68]

For AI-related initiatives, the NDRC's Department of High-Tech Industry probably plays a major role. This department is

> responsible for analyzing the dynamics of the high-tech industry and technological development. Drafts strategies, plans, and policies to promote the development of high-tech industry and advancement of technologies, organizes major industrialization demonstration projects, coordinates and synchronizes informatization development plans with national economic and social development plans and programs, organizes and promotes technological innovation and the

integration of industry, academia and research, and promotes the formation of new industries of the national economy.[69]

The National 13th Five-Year Plan for the Development of Emerging Industries illustrates the centrality of the NDRC to China's innovation initiatives. Of the 69 major projects listed in the plan, the NDRC was cited as a stakeholder in 62 of them; for comparison, MIIT was cited in 60, MOST in 42, and the Ministry of Finance in 35 of the major projects. Smaller, more specialized organizations were included in fewer programs. For example, the State Administration for Science, Technology, and Industry for National Defense (SASTIND) held a stake in only six major projects.[70]

Specific to overseeing the work of the AIDP, China's central government established the New Generation AIDP Advancement Office (新一代人工智能发展规划推进办公室) in November 2017. This office falls under the Leading Group of State Scientific and Technological Reform and Innovation System Construction (国家科技体制改革和创新体系建设领导小组). The aims of the Advancement Office are to "research AI-related laws, theories, standards, societal problems, and governance issues."[71] This Leading Group is equivalent to a vice president-led council for advanced technology, in some ways similar to the leadership body that the U.S. National Security Commission on Artificial Intelligence recommends establishing in Washington.[72] The membership of China's Leading Group was announced in September 2018 and included key members of the central government, as shown in Table 9. The daily work of the Leading Group is conducted by the Leading Group Office, located in MOST offices and chaired by the Minister of Science and Technology.

Table 9: Members of Leading Group of State Scientific and Technical Reform and Innovation System Construction, as of September 2018.

Leading Group Position	Name (Pinyin)	Central Government Position
Chairman	刘鹤 (Liu He)	Vice Premier of the State Council
Vice Chair and Head of Group Office	王志刚 (Wang Zhigang)	Minister of Science and Technology
Vice Chair	陆俊华 (Lu Junhua)	Deputy Secretary General of the State Council
Vice Chair	林念修 (Lin Nianxiu)	Deputy Director of Development and Reform Commission
Vice Chair	余蔚平 (Yu Weiping)	Deputy Minister of Finance
Member	周祖翼 (Zhou Zuyi)	Deputy Minister of the Central Organization Department
Member	梁言顺 (Liang Yanshun)	Deputy Minister of the Central Propaganda Department
Member	李章泽 (Li Zhangze)	Deputy Director of the Central Organization Office
Member	杜占元 (Du Zhanyuan)	Deputy Minister of Education
Member and Deputy Head of Group Office	李　萌 (Li Meng)	Deputy Minister of Science and Technology
Member	罗　文 (Luo Wen)	Deputy Minister of Industry and Information Technology
Member	汤　涛 (Tang Tao)	Deputy Minister of Human Resources and Social Security

Leading Group Position	Name (Pinyin)	Central Government Position
Member	张桃林 (Zhang Taolin)	Deputy Minister of Agriculture and Rural Affairs
Member	傅自应 (Fu Ziying)	International Trade Negotiator and Deputy Minister of the Ministry of Commerce
Member	曾益新 (Zeng Yixin)	Deputy Director of the Health Commission
Member	朱鹤新 (Zhu Hexin)	Deputy Governor of the People's Bank of China
Member	徐福顺 (Xu Fushun)	Deputy Director of State-owned Assets Supervision and Administration Commission
Member	刘丽坚 (Liu Lijian)	Chief Auditor of the State Administration of Taxation
Member	陈　钢 (Chen Gang)	Member of the Party Group of the State Administration for Market Regulation
Member	张　涛 (Zhang Tao)	Vice President of Chinese Academy of Sciences
Member	邓秀新 (Deng Xiuxin)	Deputy Dean of Engineering Academy
Member	周　亮 (Zhou Liang)	Vice Chairman of China Banking and Insurance Regulatory Commission
Member	方星海 (Fang Xinghai)	Vice Chairman of the Securities Regulatory Commission
Member	田玉龙 (Tian Yulong)	Deputy Director of State Administration for Science, Technology, and Industry for National Defense
Member	贺　化 (He Hua)	Deputy Director of the Intellectual Property Office
Member	李静海 (Li Jinghai)	Director of the Natural Science Foundation of China
Member	怀进鹏 (Huai Jinpeng)	Secretary of the Party Leadership Group of China Association for Science and Technology
Member	刘　胜 (Liu Sheng)	Deputy Director of the Equipment Development Department of the Central Military Commission
Member	刘国治 (Liu Guozhi)	Director of the Science and Technology Committee of the Central Military Commission

Source: 张艳玲 [Zhang Yanling], 国家科技体制改革和创新体系建设领导小组调整 刘鹤任组长 [Leading Group of State Scientific and Technological Reform and Innovation System Construction New Group Leader Liu He], Sohu.com, September 7, 2018, https://www.sohu.com/a/252475149_116897.

Reinforcing the interdisciplinary nature of AI and its high priority within the central government, the New Generation AIDP Advancement Office, under the Leading Group, includes membership from 15 ministries or specialized governmental organizations:

1. Ministry of Science and Technology
2. Development and Reform Commission
3. Ministry of Finance
4. Ministry of Education
5. Ministry of Industry and Information Technology
6. Ministry of Transport
7. Ministry of Agriculture

8. Health and Family Planning Commission
9. Chinese Academy of Sciences
10. Academy of Engineering
11. Natural Science Foundation
12. Central Military-Civil Integration Development Committee Office
13. Military Commission Equipment Development Department
14. Military Commission Science and Technology Committee
15. China Association for Science and Technology.[73]

Most of the listed ministries also hold positions in the Leading Group, and it is possible that the same government representatives would serve on both the Leading Group and in the Advancement Office. Some ministerial involvement is expected, as is the case with MOST, MIIT, and NDRC. Similarly, the Natural Science Foundation-China (NSF-C), China Association for Science and Technology (CAST), and academies of science and engineering are regularly engaged in AI research. Other industry partners, such as the Ministries of Transport and Agriculture and the three military-related organizations, are important partners for developing and implementing AI applications.

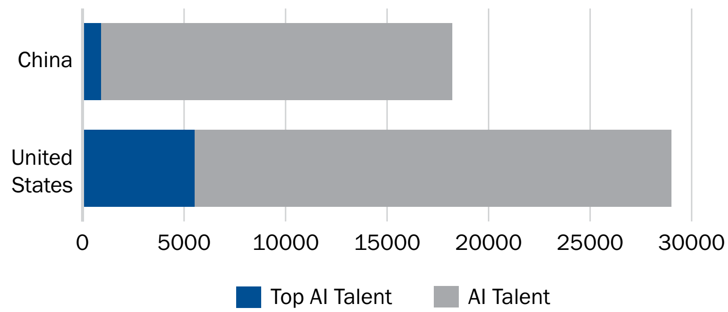
Under the direction of some of the CCP's highest ranking members, the central government allocated in 2018 at least $138 million in direct funding for non-defense AI R&D programs. Government guiding funds, which subsidize venture capital investments, injected between $2 billion and $6 billion that same year.[74] These numbers, published by the Washington think tank Institute for Defense Analysis, represent a conservative estimate of Chinese AI investment. Due to the variety of funding mechanisms and opacity of CCP budgets, an exact value for government spending on AI cannot be assigned with any confidence. This uncertainty is especially valid when looking at defense AI R&D funding. CSET estimates that in 2018, China's defense agencies invested from $300 million to $2.7 billion in AI R&D programs, based on rough approximations from the total defense R&D budget.[75] Nevertheless, China clearly is investing heavily in AI, with publicly-funded programs at least on the same order of magnitude as those in the United States.

Government involvement and leadership set the tone not only for research and development, but also for how people view the technology. By framing AI as a cornerstone for economic growth and highlighting its applications in state-run media, China has seeded popular support and strong domestic demand for AI products.

Talent

Access to high-quality researchers and innovators is the most vital requirement for national success in AI. Without people and know-how, no amount of funding or strategic guidance will produce results. For years, China has been growing its ability to train and educate AI talent, but the United States still leads the world in both total AI talent and top AI talent (see Figures 9-11). One way to measure top AI talent is by "the most productive and highly cited authors."[76] Contributions to the field by top talent in the United States and China can be seen in the relative shares of the top 10 percent and the top 1 percent of AI papers and, in both of these categories, Chinese researchers are poised to overtake U.S. researchers in the coming five years.[77]

Figure 9. Concentration of AI Talent



Source: Data used in preparing this figure from SCMP Research, China AI Report 2020, South China Morning Post, February 2020.

Top-ranked papers across most academic disciplines are published in English. However, the recent boom in Chinese research output has also spurred the creation of numerous Chinese language technical journals. These journals include those published by professional societies and research universities, as well as government and military research institutions. Chinese language publications have a much narrower readership than English language journals, as reflected in lower international rankings, but have the benefit of lowering barriers to publication for Chinese academics. According to Scimago Journal Rank, China has only seven journals ranked in the top 602 indexed publications on AI. The highest-ranked Chinese journal, *Computational Visual Media*, ranks 87th and is an English language journal published by Tsinghua University Press. The next best ranking is a Chinese language journal published by the Chinese Academy of Sciences titled 机器人 [*Robots*], ranked 217th.[78] One concern about this trend is that Chinese researchers will commonly have access to publications in both languages, while American researchers have reduced access to Chinese papers. Furthermore, if Chinese AI researchers decided to stop publishing in English, such a move would have a serious impact on international research communities.

Figure 10. China and U.S. Share of Top 10 Percent of AI Papers

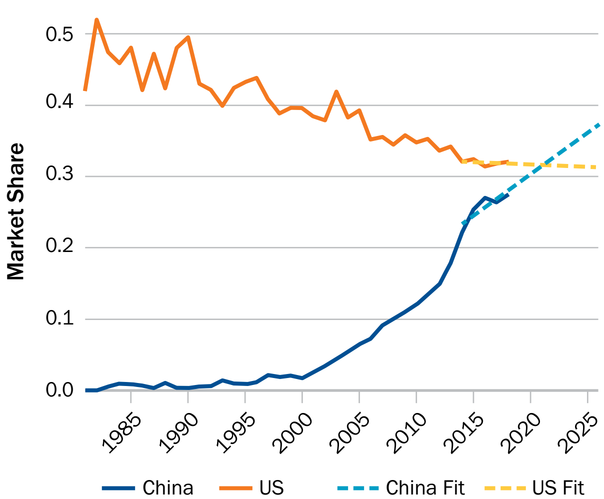
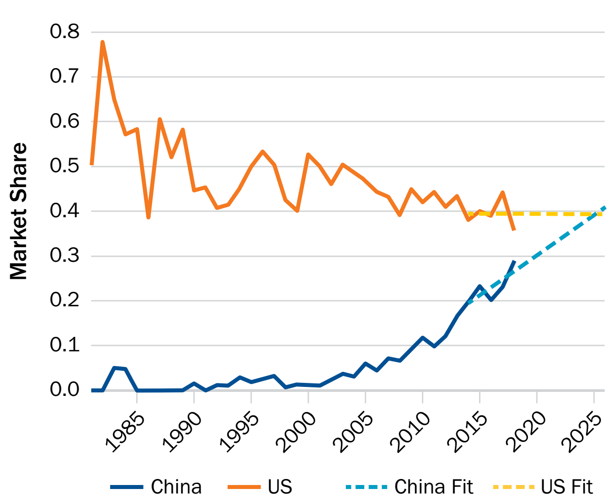


Figure 11. China and U.S. Share of Top 1 Percent of AI Papers

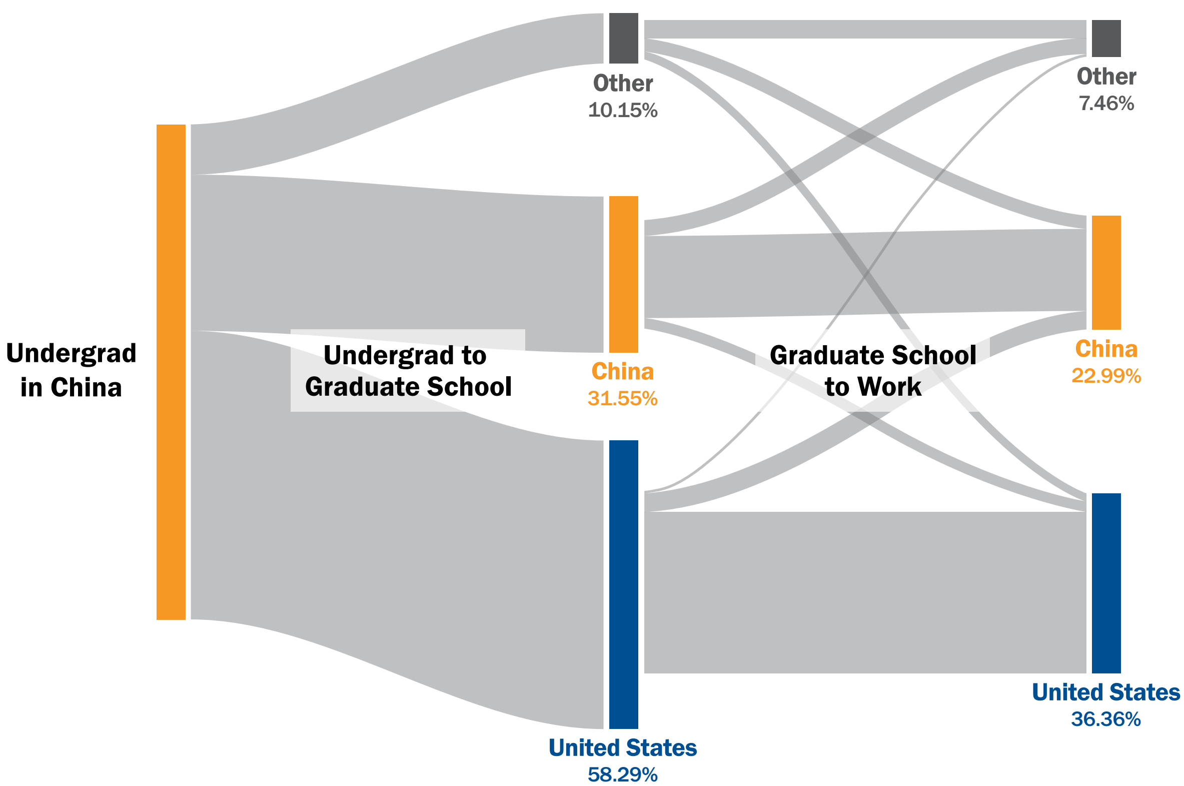


Source: Data used in preparing this figure from Field Cady and Oren Etzioni, "China May Overtake US in AI Research," Medium AI-2 Blog, Allen Institute for Artificial Intelligence, March 13, 2019, https://medium.com/ai2-blog/china-to-overtake-us-in-ai-research-8b6b1fe30595.

Thanks to recent economic gains and expanding educational opportunities, the number of Chinese researchers engaged in broader R&D activities, of which AI-related R&D comprises a non-trivial portion, continues to climb. Most R&D researchers in China "are distributed across five institutional sectors: the Chinese Academy of Sciences (CAS), research-oriented universities, industrial enterprises (especially the larger state-owned enterprises and private firms), public research institutes reporting to government ministries, and the research ecosystem serving the military."[79]

An assessment of papers submitted to the 2019 Conference on Neural Information Processing Systems (NeurIPS) illustrates recent trends in AI talent flow, as shown in Figure 12. NeurIPS is a top-tier AI professional conference that attracts several thousand research paper submissions every year from authors representing the most active AI researchers in the world. Chinese researchers who complete graduate degrees at U.S. universities have a clear propensity to remain in the United States for postgraduate employment: "Of 128 researchers with undergraduate degrees from Chinese universities whose papers were presented

Figure 12. Education Path of NeurIPS 2019 Authors with Undergraduate Degrees from China



Note: The final column of this figure, illustrating the post-graduate work locations of NeurIPS 2019 authors who earned undergraduate degrees in China, does not sum to 100 percent because not all sampled authors had work locations available, in many cases probably because they are still in graduate school and not yet in the workforce.

Source: Data source: https://macropolo.org/digital-projects/the-global-ai-talent-tracker/.

at the A.I. conference, more than half now work in the U.S."[80] Because the data set represents Chinese authors currently working in AI research, their location choices for graduate school and subsequent employment all occurred in the past. Thus, this snapshot is retrospective and may not capture possible recent changes in the trend due to improved research opportunities inside China and escalating tensions between the United States and China.

Professional Associations and Industry Alliances

National and regional associations and alliances for AI play a large role in the CCP's growth strategy. The focus on military-civil fusion (MCF) further elevates the critical role that scientific professional associations (SPAs) play in China's AI ecosystem. SPA is an umbrella term that covers societies, federations, consortia, associations, and alliances. Membership in these professional groups generally spans a wide range of experience levels representing private industry, government, and academia. Larger, high-visibility SPAs will align themselves with national strategic priorities—especially in the case of AI SPAs that directly support the AIDP. SPAs all have slightly different missions, but many can be seen hosting conferences and workshops, sponsoring competitions, and creating special cross-functional teams or working groups. Editorial control over professional journals permits SPAs to nudge academics to align research with the groups' (and the nation's) strategic research priorities. Additionally, larger societies will sponsor prestigious awards for career and student research or professional contributions. Leadership in national-level SPAs reflects success both politically and professionally and implies a high degree of personal capital and connectedness.

The CSET report *China's Access to Foreign AI Technology* points to SPAs as an important avenue by which the CCP gains access to foreign technology to supplement domestic development.[81] Western biases tend to lead Americans to view SPAs through a non-profit or academic lens, affording them greater freedom of action than would be granted to corporations or government entities. However, leaders of large Chinese SPAs are often affiliated with government labs, large corporations, or the academies of science and engineering. These high-profile groups are clearly aligned with the CCP and often have links to party committee activities right on their home page (see Figure 13).

Thus, as SPAs undertake activities that provide access to foreign talent, foster high-level collaboration, establish interdisciplinary research teams, develop cutting-edge applications, and contribute to industry standard setting, their long-range objectives should be viewed as an extension of the CCP's strategies for S&T innovation.

During a 2019 report on progress toward AIDP goals, Liu Gang, chair of the New-Generation AI Development Strategic Research Institute, announced that at least 117 AI-industry SPAs in China were working to coordinate the research

Figure 13. China Computer Federation Main Page Link on (CCP) Party Building

Image text reads, "Publicize and implement Xi Jinping thought. The CCP's spirit of the 19th National Congress." Source: China Computer Federation (website), www.ccf.org.cn.

efforts of 745 AI enterprises across government, academia, and industry by fostering an open environment.[82] National-level cheerleading about the number of SPAs indicates that the CCP cares about quantity as a metric. Additionally, as was seen during the COVID-19 outbreak (see next section), SPAs are an important conduit for coordinating industry response to national initiatives.

The size and scope of SPAs vary from small, local specialty groups to large international associations, so to describe them all with a broad brush would be counterproductive. Instead, this research looks at three large SPAs that are clearly intertwined with the CCP in AI policymaking and standard-setting within China. The Chinese Association for Artificial Intelligence (CAAI), China Computer Federation (CCF), and China Artificial Intelligence Industry Alliance (AIIA) each represent a major aspect of how AI SPAs drive innovation and facilitate AI adoption in China.

Chinese Association for Artificial Intelligence

CAAI, launched in 1981, states that it is fully committed to using members' academic strengths to support government initiatives through scientific decision-making and consulting services.[83] The association is registered as a state-level organization under the China Association for Science and Technology (CAST), the largest organizational body for scientists under the CCP.[84] CAAI is a well-established leading organization in the field of AI and, as such, sponsors prestigious awards, funds and organizes international AI conferences, and publishes domestic and international journals, such as *CAAI Transactions on Intelligent Systems, CAAI Transactions on Intelligence Technology,* and *International Journal of Advanced Intelligence*.

Among the examples of large AI conferences sponsored by CAAI is the Asian Conference on Artificial Intelligence Technology (ACAIT) 2019, held in Chongqing, China. The stated purpose of this conference was to "build a high-end and cutting edge exchange platform with a joint industry-university-research connection in the field of AI in China and promote the integration and sharing of technological innovation resources in this field worldwide."[85] The international reach of this conference is evident from its list of sponsors, which included CAAI, the Japanese Society for Artificial Intelligence, the Korean Institute of Intelligent Systems, and the Korean Institute of Information Scientists and Engineers Artificial Intelligence Society. Furthermore, CAAI set the tone of the conference with two CAAI vice chairmen serving as conference cochairs, and Li Deyi, former CAAI Chairman, giving the keynote address. As is the case at most technical conferences, accepted papers on

Table 10: Topics from ACAIT 2019 Call for Papers

Topics of Interest for ACAIT 2019	Chinese-only option
AI-related brain and cognitive science	
Machine perception and human-machine interaction	Yes
Machine learning and data mining	
Pattern recognition and computer vision	
Intelligent information processing	Yes
Natural language processing	
Network intelligence and mobile computing	Yes
Intelligent control and decision	Yes
Robotics and intelligent systems	Yes

Source: Asian Conference on Artificial Intelligence Technology (ACAIT), (list on website), accessed November 13, 2019, http://www.acait.cn.

topics shown in Table 10 were published in conference proceedings,[86] and authors of high-quality papers were invited to contribute expanded articles to other professional journals.[87] Notably, some topics were offered the additional option to be published in Chinese only in Chongqing University of Technology's *Natural Science* journal. This narrower list of topics suggests that the editors had a particular interest in these topics—possibly to increase publication counts for academics or to create a barrier of *soft-encryption*[*] to restrict readership only to Chinese-speaking audiences.

China Computer Federation

The CCF, also registered with CAST, was founded in 1962 to "promote the progress of computer research, education, industry, and applications in China."[88] Federation leaders come from Chinese universities, research labs, and businesses, as well as a handful of overseas directors in the United States, Hong Kong, and Macau. CCF hosts a variety of annual technical conferences, competitions, and technical talks known as Advanced Disciplines Lectures.

In addition to these activities, the federation sponsors the English-language international journal *Data Science and Engineering*, an open-access journal that charges no publication fees. Most journals either charge a fee to authors for publication or charge for readership through subscriptions or individual download fees. The absence of fees indicates that the CCF is providing all necessary funds and manpower to support the editorial and publication process for this journal.

As a large organization, the CCF embodies several working committees and specialty committees for accomplishing major tasks. Additionally, CCF organizes special teams, technical lectures, and workshops to address cutting-edge computational topics. For example, the Intelligent Robot Special Team (IRST), established in October 2019, is a special interest group focused on directing investments to drive innovation in intelligent robotics. According to Microsoft AI Lab, "Intelligent Robotics uses AI to boost collaboration between people and devices. AI helps robots to adapt to dynamic situations and communicate naturally with people."[89] Made in China 2025, National Key R&D Programs (2017-22), and the 13th Five-Year Science and Technology Innovation Plan's 2030 Innovation Megaprojects all list intelligent robotics as a major component. The IRST aims to coordinate research related to this priority R&D area to accelerate the fielding of applications. This team will "encourage interchange between academia and industry" to "more quickly move Intelligent Robotics to industry," with ideal team members being "talented people experienced in robotic control systems and software, perception theory and methods, robotics theory and methods, map-making, positioning, navigation, and human-machine teaming."[90] The COVID-19 response demonstrated several applications of robots helping with deliveries and disinfection. However, it is also important to note the dual-use nature of such technologies for autonomous combat and support systems on land, at sea, and in the air.

---

* Soft encryption is a term used to describe the natural barrier posed by presenting information in a foreign language. Machine translation is reducing this barrier, but for some language pairs like Mandarin-English these tools are far from perfect.

China Artificial Intelligence Industry Alliance

The AIIA is a consortium of more than 400 companies and universities that was established in 2017 to lead the national discussion on AI frameworks and ethics. The alliance is overseen by the China Academy of Information and Communications Technology (CAICT), which in turn is subordinate to MIIT. This direct linkage between AIIA and China's central government indicates that AIIA plays a large role in implementing national strategies like the AIDP. Technology heavy-hitters Alibaba, Baidu, Harbin Institute of Technology, Huawei, Qihoo 360, Tencent, Tsinghua University, Zhejiang University, and Zhongxing Telecommunications Equipment (ZTE) hold key vice chair council positions.[91] In a commentary about AIIA, Jeffrey Ding, researcher at the Center for the Governance of AI at Oxford's Future of Humanity Institute and editor of *ChinAI Newsletter*, has written: "What is most interesting about this report is the insights into how AIIA thinks and frames certain issues—it's an interesting hybrid body that appears to be a mix between the lobbying arm of the AI industry and an industrial planning body."[92]

Using its high-visibility position, AIIA has led the discussion on standards and norms among AI practitioners with its 2019 publication of the *Joint Pledge on Artificial Intelligence Industry Self-Discipline*. This pledge for self-discipline goes hand in hand with the *Beijing AI Principles*, published by the Beijing Academy of Artificial Intelligence in conjunction with numerous leaders in the AI industry including "Peking University, Tsinghua University, Institute of Automation and Institute of Computing Technology in Chinese Academy of Sciences," and probably AIIA.[93]

AIIA organizes or underwrites AI-themed educational events, such as its annual Zhejiang Lab Cup. A global competition, the 2019 Zhejiang Lab Cup attracted more than 1,700 team submissions to AI challenge tasks addressing technical or innovative solutions. After initial submissions were reviewed, 41 international finalists participated in the live event. This competition is a prime example of academic, government, and private sector organizations working together to promote strategic goals. Co-organizers of the event were the Zhejiang Lab, AIIA, China Institute of Communications, and the Hangzhou municipal government.[94] According to AIIA, the Zhejiang Lab's purpose is "attracting talents, facilitating research, and boosting industry development… so that China will create its own AI tech innovation hub and gradually take the lead in AI research and development."[95] This mission statement is unapologetic about its desire to help China access foreign talent and innovation.

COVID-19:
A Case Study for Understanding the AI Ecosystem

China's experience during the 2003 SARS outbreak is an important backdrop to its response to COVID-19, as seen not only in its initial sensitivity to acknowledging the outbreak of a new SARS-like pneumonia,[96] but also in its response plan. According to a 2003 report to the World Health Organization on SARS, Beijing learned two key lessons from the SARS outbreak: the value of strong government leadership and the need to rely on science and technology. Other takeaways were the necessity to improve legislation, mobilize the people, and cooperate internationally. China's plans to prepare for future epidemics included "establishing outbreak alert & response system" and "improving disease control system."[97]

In addition to technologies designed specifically to address epidemic prevention and control (EPC), medical big data has grown in importance for streamlining medical care across China. In fact, the Big Data White Paper published by the China Academy of Information and Communications Technology in December 2019, right before the COVID epidemic was recognized, states:

> Medical big data has become a hot topic for big data applications in 2019. The Administrative Measures for National Health and Medical Big Data Standards, Security and Service promulgated by the National Health Commission of China (NHC) in July 2018 provided a blueprint for the development of big data services in the health industry. **Electronic health records**, **personalized diagnosis and treatment**, **medical knowledge graph**, **clinical decision support system**, and **R&D of drugs and devices** have become hot spots in the industry [emphasis added].[98]

This commitment to integrating data services into the medical industry played a major role in China's ability to quickly respond to COVID-19 with medical applications for detecting the virus and tracking its spread.

According to official Chinese sources, the first observed case of the illness happened in early December, 2019, and official reports out of Wuhan were made prior to the new year.[99] The Wuhan Municipal Health Commission's report stated that several cases of pneumonia had been linked to the Huanan

Seafood Wholesale Market, where further investigation into the virus would begin immediately following the report's submission on December 31.[100] At the time of the initial report, 27 cases had been diagnosed. Seven of those were reported to be severe, two had already recovered and left the hospital, and the remaining 18 were listed in stable condition. The report also described presenting symptoms as mainly fever and, in some cases, respiratory difficulty and lesions of both lungs visible on chest X-rays. Finally, the report stated that contact tracing and medical evaluation had already begun.[101]

Notably, the medical community in Wuhan had already begun suspecting that this virus might be spreading. On December 30, 2019, Li Wenliang posted a message to other medical professionals about the SARS-like pneumonia on an online chat room, warning doctors to protect themselves from infection. A few days later, "he was summoned by the authorities and forced to sign a statement denouncing his warning as an unfounded and illegal rumor."[102] While most of the reporting on technology and COVID-19 focuses on new tools and applications for EPC, it seems that the earliest impact of China's techno-authoritarianism was to prevent the spread of information about the potential dangers.

While there is ongoing debate about the origins of and culpability for the global coronavirus pandemic, Taiwan serves as a poignant counterexample to much of the world's response. When doctors in Taiwan received Dr. Li's message, they immediately began examining travelers inbound from Wuhan.[103] As of December 16, 2020, Taiwan had reported only 741 total cases of COVID-19 leading to 7 deaths among its 23.8 million residents.[104]

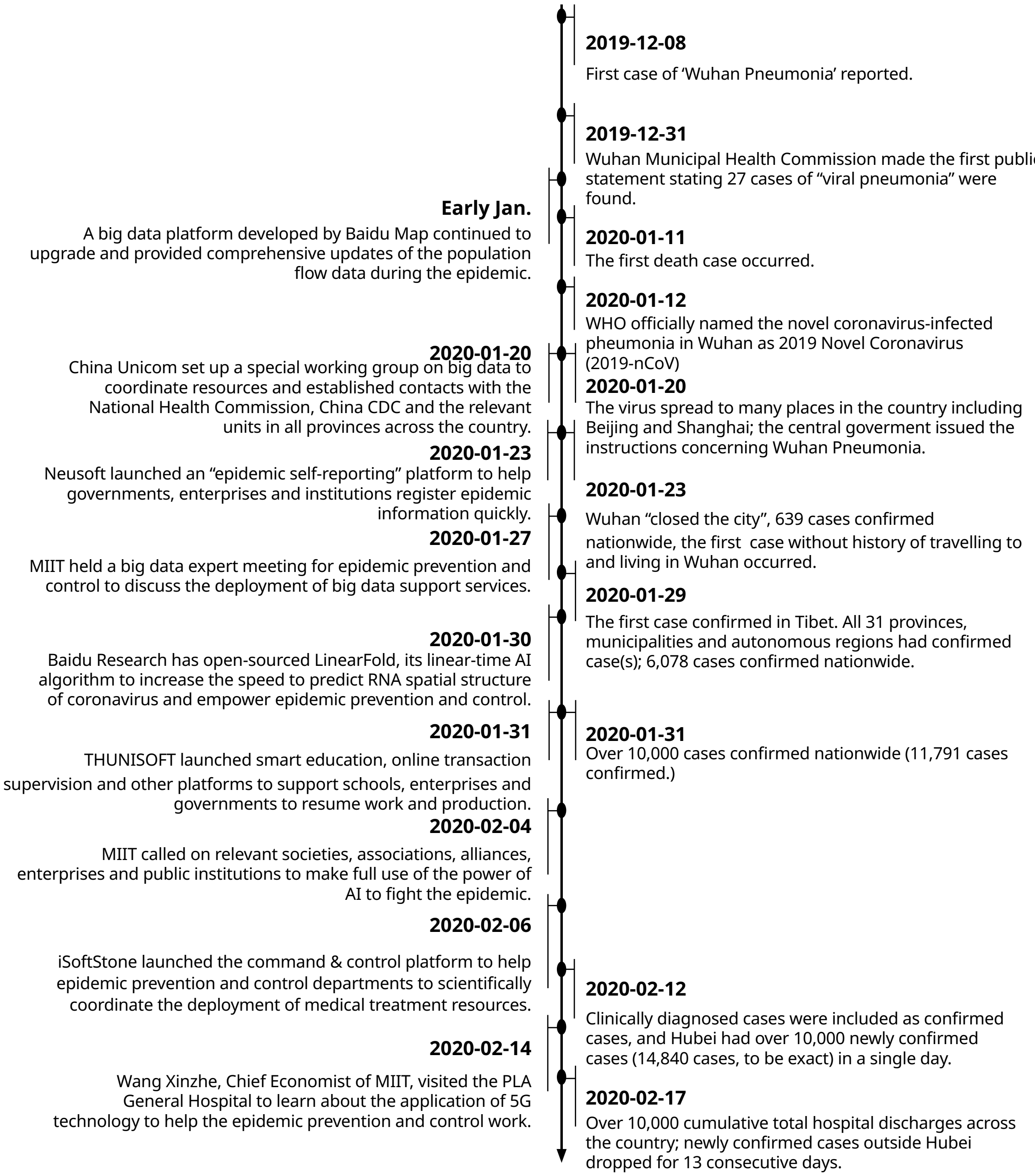
Technological Solutions for Epidemic Prevention and Control (EPC)

The timeline in Figure 14 shows that Baidu Map was one of the earliest technology companies to start tracking the virus with population flow models. China Unicom Big Data established its special working group on January 20, 2020, probably laying a foundation for data and information exchange that would be necessary for EPC-related applications and solutions. From the government side, MIIT appears to have led the charge for stimulating and integrating the technology industry for EPC.[105]

After locking down Wuhan[106] on January 23, and subsequently all of Hubei Province, the CCP's rhetoric turned to unifying the nation against the virus. As stated in an online official commentary, "China has fortified a nationwide defense against novel coronavirus."[107] Simultaneously, China circulated its first nationwide calls for high-tech solutions. A January 26 article in the *People's Liberation Army Daily* said the tech industry would play a pivotal role, specifically through emergency R&D on disease transmission, rapid testing, corrective treatments, and vaccine development.[108]

Within two weeks of the lockdown and national attention being focused on battling COVID-19, on February 4, the central government put out a call for AI solutions. This initiative was announced by MIIT and advertised through various AI professional societies and alliances. Addressing the notice to all AI-related academic and professional societies, alliances, businesses, and organizations, MIIT established that the

Figure 14. Chinese Timeline of COVID-19 Response



Source: China Academy of Information and Communications Technology, Research Report on Data and Smart Applications for Epidemic Prevention and Control, Version 1.0, People's Republic of China, March 2020.

first stated goal was to use artificial intelligence technology to fill gaps in EPC technology, promoting rapid industrial production and applications.[109] Aside from EPC-specific requirements, MIIT also addressed tools needed to keep the economy productive with applications for telework and online education. This initiative aimed to unify the efforts of all AI-related professional associations, researchers, and enterprises.

Figure 15. Examples of QR Codes

Green: No known risk—proceed. Yellow: Elevated risk—stay at home for one week. Red: High risk—quarantine for two weeks. Source: www .shanghaieye.com.cn/how-to-get-your-health-qr-code-using-alipay/.

Perhaps the most widely publicized application for EPC was contact tracing. One contact tracing application that has received a lot of press coverage has been the so-called "health code." This is a stoplight-colored QR code that alerts users to possible risks based on historic travel and geolocation data (see Figure 15). According to the CAICT Research Report on Data and Smart Applications for Epidemic Control and Prevention, as a result of China's "mobile phone real-name registration reform," where valid ID cards are needed to activate a SIM card, "the comprehensiveness, authenticity, and real-time nature of telecom big data has fully demonstrated its value."[110]

This app pairs location data with public safety reports about confirmed cases to alert people when they have been in shared locations. This data fusion problem is not trivial, as the necessary data comes from various sources and would likely be in different formats. Despite this challenge, ANT Financial, the Alibaba subsidiary responsible for Alipay, rolled out its first test on February 11 in Zhejiang Province. The app received 100 million queries on the first day and, within a week, the government decided to implement a nationwide version delivered on either Alipay or WeChat.[111] The speed of development and implementation is unnerving, especially because these color codes directly impact people's daily lives. During the height of the pandemic, citizens were required to show the QR code to board transportation, check into hotels, or access certain public spaces,[112] a practice that continued months after China claims to have brought the spread of COVID-19 under control.

The rapid rollout of health monitoring technology understandably has raised questions about ethical data sharing and privacy, flagging an issue that is deeply interconnected with cultural norms and values. Generally, Chinese digital consumers are becoming more cognizant of their online data profiles despite "the conventional wisdom that the Chinese internet industry has a tremendous amount of user data accumulated for AI research thanks to lax regulation on data collection in China."[113] Nevertheless, Chinese culture still emphasizes collectivism, where individuals are routinely willing to make personal sacrifices for the good of the masses.[114] Thus, Chinese citizens understand that the Chinese government is collecting and storing their individual data but expect that these data will not be routinely shared in public forums or social media. Early in the COVID-19 outbreak, private data were handled loosely as apps and algorithms rushed to identify risks. Potentially, identifying these weaknesses may lead to enhanced privacy practices in future Chinese systems.

Privacy amid Pandemic

People and companies around China, likely in a good-faith effort to stem the spread of COVID-19, committed numerous acts of inappropriate or unlawful data sharing. "Documents containing personal information were suddenly reposted on social networking platforms such as WeChat and Weibo, including the names, photos, employer units, schools, home addresses, mobile phone numbers, and ID numbers of relevant personnel." This widespread failure to protect personal data negatively impacted people's daily lives.[115] This is not to say that China does not have laws in place to protect privacy but does align with the generalization that the Chinese are collectivist and value the good of the many over the rights or freedoms of the few. Existing privacy laws were summarized by CAICT as follows:

> Articles 110 and 111 of the General Principles of the Civil Law of the People's Republic of China stipulate that citizens enjoy the right to privacy and personal information is protected by law. No organization or individual shall illegally collect, use, process, or transmit the personal information of others, or illegally trade, provide, or disclose the personal information of others. Article 12 of the Law of the People's Republic of China on Prevention and Treatment of Infectious Diseases also stipulates that the disease prevention and control institutions and medical institutions shall not disclose relevant information and materials related to personal privacy.[116]

Specifically addressing the widespread data collection and sharing to fight COVID-19, the Cybersecurity Administration of China issued the "Notice on Doing a Good Job in Protecting Personal Information and Using Big Data to Support Joint Prevention and Control"[117] on February 4, 2020. This notice strongly advocated for the use of big data tools on personal data but clearly stated limitations on sharing identifiable information, such as name, age, or ID number, without consent.

Major Lines of Effort for EPC

The COVID-19 response from the tech sector was vast and impressive. Large companies developed nationwide applications, led business consortia, and dedicated their computational resources to solving COVID-19-related problems.

The AI office of China Industrial Control Systems Cyber Emergency Response Team (CIC)[118] published a special report listing 76 specific applications developed by 69 different companies in response to the COVID-19 outbreak. The CIC report broke applications into six major categories: 1) precise EPC, 2) information systems assurance, 3) medical supplies deployment, 4) medical prevention measures, 5) enterprises return to work—return to production, and 6) quality of life assurance.[119]

Tremendous resources were poured into AI applications for medicine. From diagnostic imaging tools to genome sequencing and vaccine development, big data played a major role in China's strategy to bring the virus under control. Synced Review published a list of 761 AI solutions non-uniquely assigned to 12 different use scenarios for responding to COVID-19. Of the 761 solutions, 75 were categorized under medical imaging analysis and diagnosis, and 154 were considered under virology research and drug discovery.[120]

Examples of medical applications designed by the largest AI leaders in China are:

- Alibaba developed a computer diagnostic model to assist with rapidly diagnosing CT scans for suspected cases of COVID-19.
- Baidu provided its Linearfold program to researchers around the globe to speed up vaccine development.

- Tencent committed its supercomputing resources to aid the search for a vaccine and created an AI medical innovation system capable of accurately screening lung CT scans in just one minute.[121]
- Huawei, partnering with GrandOmics Biosciences, developed tools for better understanding the coronavirus genetic code. Additionally, Huawei technology helped with drug screening and analysis of CT scans for diagnosing patients.[122]

In addition, iFlyTek used its natural language tools to develop a realistic AI voice assistant to interview and screen as many as 800,000 people per day for symptoms related to coronavirus. Notably, their robot doctor "has passed the written test of China's national medical licensing examination, an essential entrance exam for doctors."[123] These natural language processing-based robo-callers canvassed large swaths of the Chinese population with telephone screenings to provide a better picture of potential spread rates and upcoming hot spots.

Megvii (旷视科技), known for its Face++ software, developed a data processing system that could handle as many as 300 temperature scans per minute. This application prevented queuing at high-traffic locations and removed the risk of transmission presented by hand-held scanners.[124]

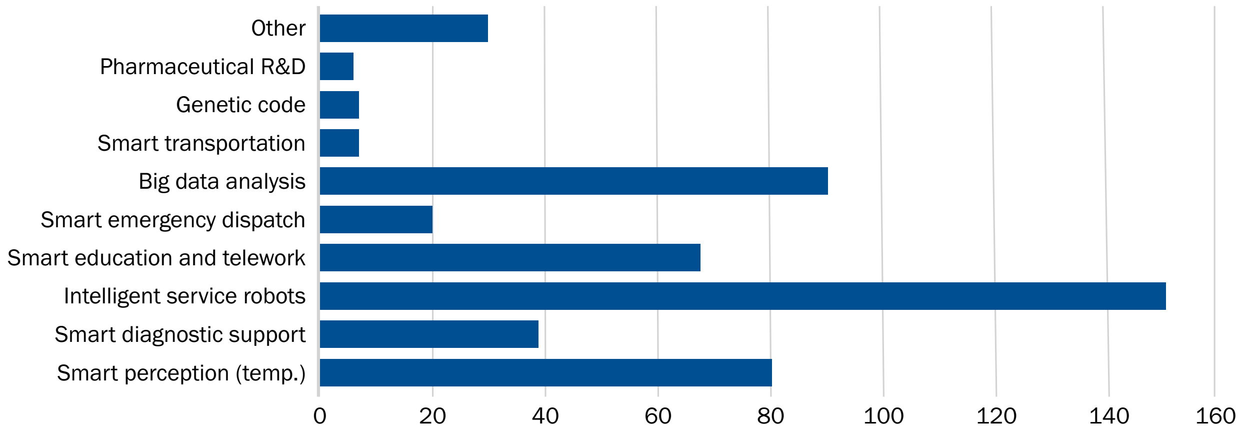
Baidu—with partners including Neolix (新石器), IDRIVERPLUS (智行者), Apollo Minibus (阿波龙), Bai Xixiu (白犀休), Qingdao Wuniu Intelligent Technology Co., Ltd. (青岛悟牛科技), AgileX (松灵机器人), and Agribot (博田)—quickly joined the fight with autonomous vehicles.[125] More than 100 self-driving cars using Baidu's Apollo system performed tasks from disinfecting to logistics, transportation, and distribution of materials.[126] This serendipitous boom for self-driving vehicles may have accelerated existing efforts to field commercially viable products. As of October 2020, Baidu has started running fully autonomous taxis in Beijing. Although the company is not charging fares during initial rollout, self-driving taxis will eventually be operating throughout the city.[127]

Autonomous robots and vehicles also played a major role in EPC. Hospitals and other facilities used robots to clean and disinfect common areas, thereby reducing the risk of person-to-person transmission. Authorities used drones to monitor public spaces and disinfect large areas.

Smart temperature scanning technology was also rolled out around the country. Hospitals across China adopted AI-enhanced, fever-screening procedures, and the government deployed temperature sensors to monitor travelers and check for signs of infection. Remote temperature screening tools have been in use for several years at airports. However, the nationwide epidemic called for deployment and operation on an unprecedented scale. According to a Chinese press report, remote infrared temperature sensors from military technology used in satellites were adapted to read human body temperatures. These systems deliver readings accurate to within 0.1 degrees Celsius from up to 100 meters away.[128]

AIIA published a summary report at the end of March detailing its effort to aggregate COVID-19 solution proposals in response to the nation's demand. The Chinese consortium received more than 500 distinct proposals covering a wide range of categories; many addressed robotics, while others focused on data processing, temperature sensing for fever screening, and distance education.[129] These 500 solutions probably came primarily from smaller companies in the Beijing area, a small fraction of the total response from private companies. The variety of proposed applications is shown in Figure 16.

Figure 16. Summary of 500 AI Solutions Submitted to AIIA

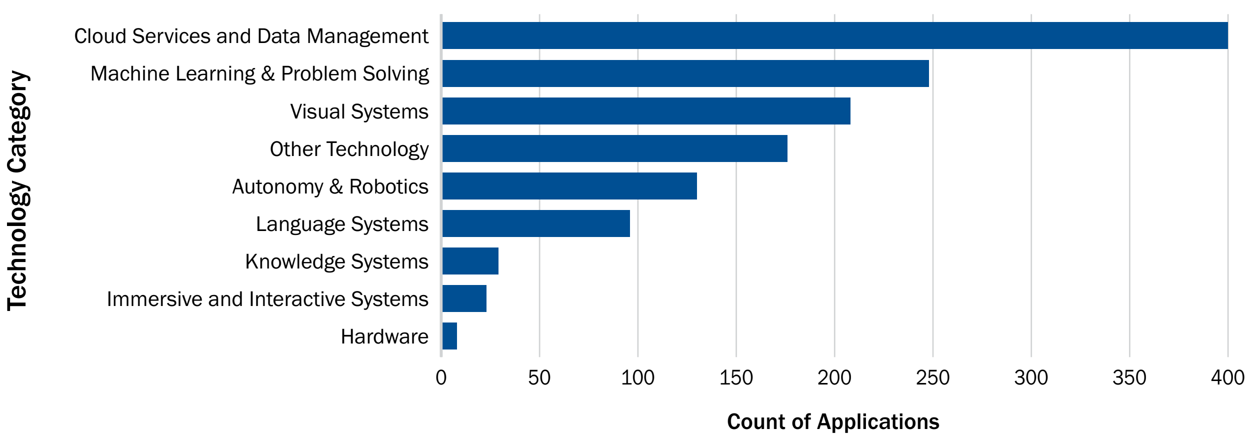


Source: Artificial Intelligence Industry Alliance (AIIA), 人工智能助力新冠疫情防控调研报告 [Research Report on AI Assisting Epidemic Prevention and Control for COVID-19], People's Republic of China, March 2020.

Figure 16 shows a surprisingly high number of robotics applications, which may indicate a large number of small businesses in the Beijing area are working in this sector. The high number may also indicate a bias in the reporting or categorization of technology areas.

While the application areas are divided into categories, many of the systems are based upon similar technological foundations. Returning to the Synced database and its 12 scenarios listing 1,428 AI solutions for responding to COVID-19, Figure 17 illustrates the most common technology areas used across 761 unique applications. The database listed 39 different technologies, which were grouped together according to the categories shown in Table 11.[130]

Figure 17. Technology Areas Used in Response to COVID-19



Source: Synced, "Artificial Intelligence Solutions in Response to the COVID-19 pandemic – China – Database," AI Against COVID-19 Vol I, Synced Review, https://payhip.com/b/i5bN.

Table 11: Summary of Technology Areas Used in COVID-19 Solutions

Category	Count	Included technology
Visual Systems	208	Computer vision, Facial recognition, Image recognition, Automated optical inspection
Language Systems	96	Natural language processing, Speech recognition, Speech generation, Semantic understanding, Natural speech synthesis
Knowledge Systems	29	Artificial general intelligence, Knowledge map, Knowledge representation
Autonomy and Robotics	130	Robotics, Automation, Autonomous driving
Machine Learning and Problem Solving	248	Data science, Deep learning, Machine learning, Supervised learning, Operations research and optimization, Unsupervised learning, Semi-supervised learning, Self-supervised learning, Model optimization
Cloud Services and Data Management	400	Big data, Information retrieval, AI infrastructure, Data management, Cloud computing
Immersive and Interactive Systems	23	Immersive technology, Human-computer interaction, Recommender systems
Hardware	8	AI Chips, Sensors, 3D Printing
Other Technology	176	5G, Blockchain, Internet of Things, Other

Source: Synced, "Artificial Intelligence Solutions in Response to the COVID-19 pandemic – China – Database," AI Against COVID-19 Vol I, Synced Review, https://payhip.com/b/i5bN.

Comparing Figures 16 and 17, there are fewer applications in autonomy and robotics reported by Synced than by AIIA, despite the Synced data set including a larger set of solutions. The most prevalent technology areas are those that underpin nearly all AI systems: data management and machine learning. More expensive and specialized systems, such as AI chips, immersive systems, and knowledge maps, have the lowest frequency. Visual systems, autonomy, and interactive language systems are in the middle of the pack. This medium frequency indicates that these applications were commonly employed in response to COVID-19 and that a significant number of Chinese companies are working in this space. Also worth noting is the prevalence of "other" applications. Both Figures 16 and 17 show "other" applications near the middle in terms of relative frequency. This is a testament to the adaptability of AI applications to solve problems, link with other technologies, and apply methods that may not easily fit into a limited number of fixed categories.

AI Ecosystem's Effect of COVID-19

This national crisis exemplified exactly how AI is a different type of enabling technology. Unlike traditional engineering projects, which require a long design and development process and an established industrial base, algorithms hosted on cloud servers can be developed quickly and made available for use with the click of a button. Rather than starting up a major industrial production, manpower and tools can immediately be reoriented to support new priorities. Government led the calls and provided the support required to bring solutions to the places they were needed. The reporting on Beijing's call for solutions to COVID-19 and private industry's response makes it evident that—although small companies often worked through middlemen, either industry alliances or consortia led by larger companies—the National Team members led their own groups and projects. Still, the call for help was very broad—asking for any and all ideas to use AI in the fight against COVID. This sort of open-ended announcement helped to stimulate innovation.

Private industry responded quickly with AI giants leading their own projects and smaller industry players doing what they could to help. The smaller companies do not always have the same visibility as the large companies, so they need the most help to bring their ideas to the front lines. Help came from key integrators like professional associations and alliances. For example, in the city of Jinan in Shandong Province, the Jinan Artificial Intelligence Industry Innovation and Development Alliance (AI IIDA) helped bridge gaps between the government and local industry. The Jinan AI IIDA was established by the local Bureau of Industry and Information Technology in September 2019 with the mission to aggregate, integrate, and organize industry leaders and to bring together manufacturing, academics, research, industry, commerce, and funding.[131] In response to COVID-19 and in support of the MIIT-led AI initiatives, the alliance claimed to have collected 231 solutions addressing specific needs related to EPC.[132]

The scientific professional associations played a key role in connecting solution developers from industry with government planners, collecting proposals and ideas for AI solutions and pushing them forward to address requirements around the nation. In turn, thanks to the unified efforts of the national AI ecosystem coupled with widespread testing and lockdowns, China claims to have controlled the spread of COVID-19 within its borders.[133]

Lessons Learned From the Coronavirus Response

Beginning with the shutdown of Wuhan on January 23, 2020, and the announcement of a nationwide effort on February 4, 2020, the rapid response from China's tech sector to the coronavirus has been astounding. Within two to three weeks, Alipay's close contact app was pushed to millions of users' phones across one province as a test. One week later, using lessons learned from the beta test, the system was rolled out across all of China.

China's COVID-19-driven emergency rollout of new technologies pressure-tested a wide variety of AI applications. Autonomous vehicles supported various national efforts. Military-grade thermal imaging cameras in public spaces detected fevers. Geolocation tools in health monitoring apps provided real-time notifications to people who may have been close to confirmed cases. This large-scale, rapid deployment provides a glimpse into the capacity of China's digital authoritarianism—and demonstrates the whole-of-nation effort that China would be capable of achieving should it ramp up its data enterprise to support a military mobilization. In an apparent victory lap, a spokesperson from the Ministry of Industry and Information Technology said AI played an effective role in fighting the epidemic, with the largest contributions in testing, consultation, and medicine research and development.[134]

Professional associations demonstrated their value as focal points for industry efforts. These go-between bodies may be critical nodes in future large-scale mobilization efforts. In a military conflict, governments and forces encounter new problems at every junction. Defense assets will be busy operating systems that already have been developed and deployed. It will be up to the private sector to develop innovative solutions to newly identified challenges. The coronavirus stress-tested the major muscle movements required to bring new technology to the front lines quickly. This is a testament to both the strength of China's AI ecosystem and the influence of the central government. If China were to face a similar large-scale crisis, as might be seen in a military conflict with a near-peer competitor, the private sector response probably would be even more rapid and coordinated.

Concluding remarks from a CAICT report on big data applications used for EPC summed up the efforts:

> On February 23, General Secretary Xi Jinping hosted at a meeting to advance the work on coordinating the prevention and control of the COVID-19 and economic and social development. At the meeting, he pointed out that the current epidemic situation is still grim and complex, and the prevention and control are at the most critical stage. Whether it is to analyze and judge the development and trend of the epidemic situation, accurately implement the EPC strategy, or provide convenient applications & services for the people and promote the orderly resumption of work and production, we can see that data and smart applications are playing a key role in this battle without gun smoke. Here, we call on the tech communities to unite together and give full play to the important role of data and intelligence in the prevention and control of the epidemic, be determined to fight and win the battle against the epidemic, and secure finishing the building of a moderately prosperous society in all respects and completing the 13th Five-Year Plan to achieve the victories in both EPC and economic and social development![135]

China's response to the national coronavirus crisis exemplified exactly how the AI industry is different from other industries in its responsiveness and flexibility. Tech giants like Alibaba and Baidu led projects with consortia partners and government sponsors. Smaller (e.g., micro, small, and medium) firms—both software and hardware providers—funneled their efforts through regional AI professional associations, as seen in Jinan. This organizational strategy is likely how China will respond to large-scale problems in the future.

Sino-U.S. Competition in AI

Over the past two years, several think tanks and researchers have tackled the question of relative national strength of AI industries. Although each of the reports summarized below focused on different metrics, each concluded that the United States leads the world in AI overall and China is a quickly rising second. Areas where China scored particularly well are in government strategy, adoption, robotics, supercomputers, and journal publications. This section addresses the following research questions:

> What are China's strengths and weaknesses relative to U.S. leadership in AI?
>
> What are the implications for U.S. competitiveness?

This literature review uncovers Chinese strengths in the areas of government strategy, data, adoption, robots, and AI publications. The United States is the current world leader in AI and, as such, is generally strong across all components. However, U.S. opportunities to prevail in the AI competition can be found in areas the Chinese AI industry has not prioritized, such as inclusion and diversity in its workforce. Observations and conclusions from these assessments are summarized in a modified Strength-Weakness-Opportunity-Threat (SWOT) analysis shown in Table 13 with actionable points presented at the end of this section.

Survey of Recent Assessments

Center for Data Innovation

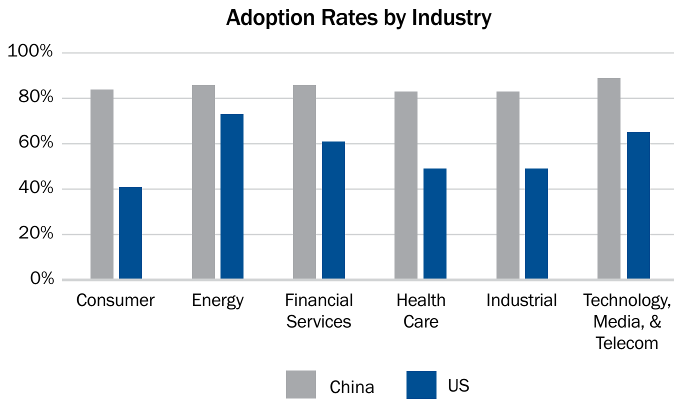
The Center for Data Innovation compared the relative strengths in AI among China, the United States, and the European Union. Consistent with other studies, they ranked the United States as first and China as second. "Out of 100 total available points… the United States leads with 44.2 points, followed by China

Table 12. Overall Rankings by AI Category

	Category					
	Talent	Research	Development	Adoption	Data	Hardware
United States	1	1	1	3	2	1
China	3	3	3	1	1	2
European Union	2	2	2	2	3	3

Source: Daniel Castro, Michael McLoughlin, and Eline Chivot, Who is Winning the AI Race: China, the EU, or the United States? Center for Data Innovation, August 2019.

Figure 18. Percentage of Firms That Have Adopted AI or Are Piloting AI in China and the United States by Industry



Source: Daniel Castro, Michael McLoughlin, and Eline Chivot, Who is Winning the AI Race: China, the EU, or the United States? Center for Data Innovation, August 2019.

with 32.3 and the European Union with 23.5."[136] Table 12 shows the overall rankings by AI category. The U.S. AI industry ranks first across four of the six categories and the Chinese AI industry ranks first in data and adoption. Access to data is a well-documented strength of the Chinese system, but adoption rates deserve to be discussed in more detail.

One of China's strengths is its adoption rates. The Center for Data Innovation study scored adoption rates based on the number of employees working at companies or firms that were either using or piloting AI technology. Figure 18 shows the comparative rates of adoption in the United States and China broken out by industry. The study authors offer up Chinese rhetoric and funding attached to the AIDP as a probable explanation for high adoption rates, as Chinese companies are eager to adopt new technology to access more government capital. Additionally, "a higher share of Chinese individuals (76 percent) believe AI will have an impact on the entire economy than individuals in the United States (58 percent), France (52 percent), Germany (57 percent), Spain (55 percent), and the United Kingdom (51 percent)."[137]

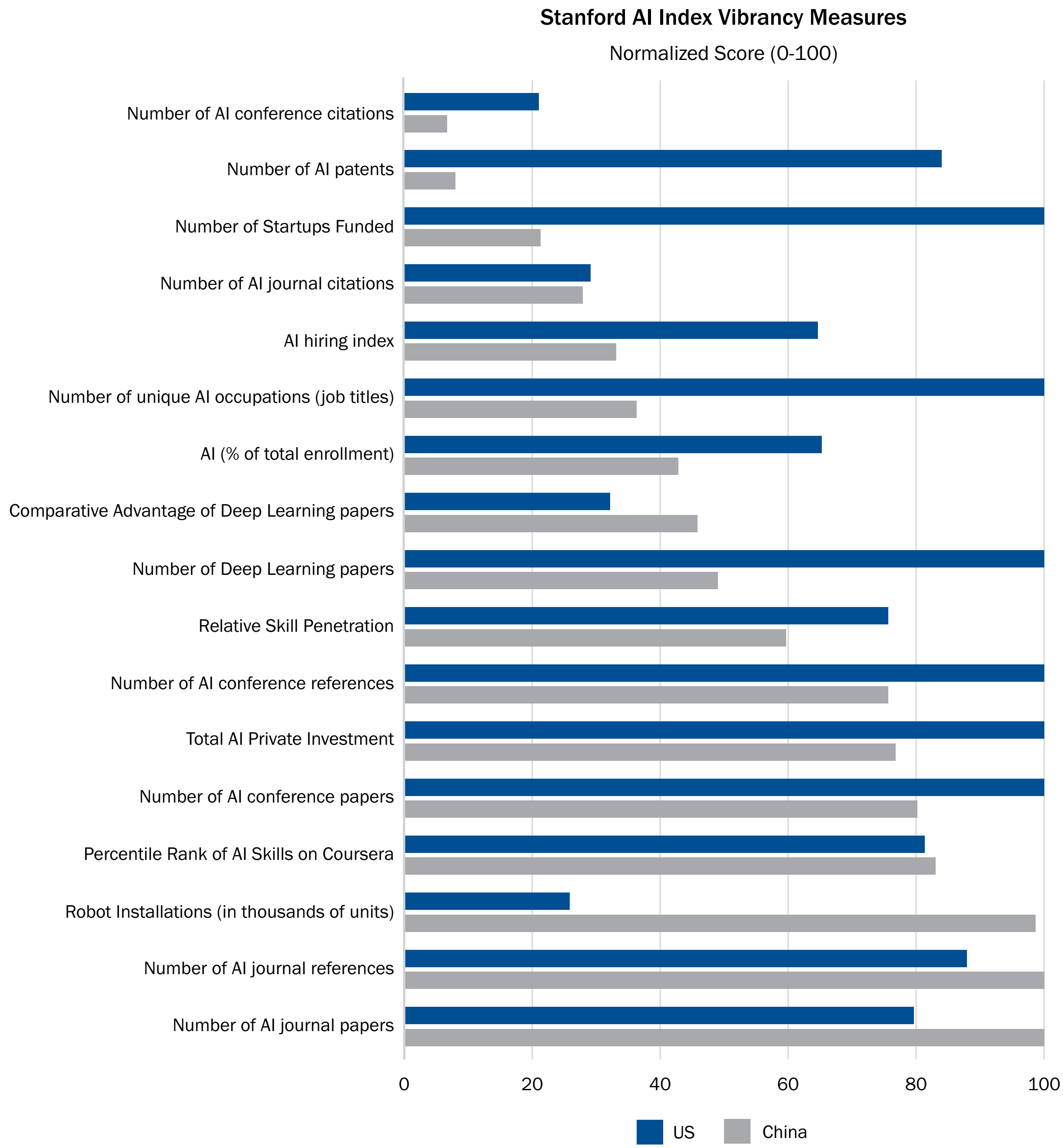
Stanford AI Index 2019

The Human-Centered AI Institute (HAI) at Stanford University compiles a wide range of measures to rank AI performance around the globe. One interesting finding is that, although China and the United States tend to be the top-ranked overall, "local centers of AI excellence are emerging across the globe. For example, Finland excels in AI education, India demonstrates great AI skill penetration, Singapore has well-organized government support for AI, and Israel shows a lot of private investment in AI startups per capita."[138]

As shown in Figure 19, HAI's AI Index scores vibrancy measures, which include investments, papers, patents, and job opportunities. In this system, the global leader is assigned a score of 100, with other scores assigned as a percentage of the leader's performance. Thus, the United States leads the world in six and China leads in two of the categories included on this chart. Measures of inclusion (data not available for China) and per capita scores are not provided.

The HAI team also identified a marked difference between U.S. and Chinese research papers. Although the vast majority of papers in both countries are published by academic institutions, those papers not affiliated with universities tend to be mainly from government sources in China. "In 2018, Chinese government institutions produced nearly three times more AI papers than Chinese corporations."[139] In the United States, corporations out-publish government sources by a factor of almost two to one.

Figure 19. Chinese and U.S. Vibrancy Measures



Source: Stanford's AI Index 2019, Human-Centered AI Institute, Stanford University, data available at http://vibrancy.aiindex.org/.

Figure 19 shows that China leads in the metrics of AI journal publications, journal references, and robot installations. On the other hand, the strength of the American AI ecosystem is evidenced by the six measures where the United States has received maximum scores. These areas are AI startups, AI occupations, deep learning papers, conference references, conference papers, and private investment.

Tortoise Media

Tortoise Intelligence, produced by the UK's Tortoise Media, has ranked the AI performance of 54 countries based on seven key pillars (see Figure 20), which are further grouped into the categories of implementation, innovation, and investment. The pillars of talent, infrastructure, and operating environment are categorized under implementation, as they are requirements for fielding AI software. Research and development fall under innovation, an area where both China and the United States are leading the world. The pillars titled government strategy and commercial are grouped under investment,[140] with the United States leading the world on the commercial side and China leading from the government side. The relative advantage of U.S. private industry is strong enough to push the Americans into the top seat in the investment category.

Figure 20. Top Five Scoring and Ranked Countries on Tortoise Media Global AI Index 2019

		Implementation			Innovation		Investment		
Country		**Talent**	**Infrastructure**	**Operating Environment**	**Research**	**Development**	**Goverment Strategy**	**Commercial**	**Total**
United States of America	Score	100	100	80.4	100	89.4	68.5	100	**100**
	Rank	1	1	6	1	2	13	1	**1**
China	Score	15.8	93.1	89.4	52	100	100	34.4	**58.3**
	Rank	18	3	3	2	1	1	2	**2**
United Kingdom	Score	31.8	78.1	100	37.8	20	88.2	22.6	**43.7**
	Rank	5	8	1	3	11	7	4	**3**
Canada	Score	32.8	62.9	80.9	29.4	20.3	96.7	15.2	**37**
	Rank	4	23	5	8	10	4	5	**4**
Germany	Score	23.4	73.3	77.2	33.3	19.5	96.3	8.7	**35.3**
	Rank	9	12	7	4	12	5	9	**5**

Source: Ella Hollowood, "Countries in Focus," The Global AI Index, Tortoise Media, December 3, 2019, https://members.tortoisemedia.com/2019/12/03/global-ai-index-2-countries/content.html.

The overall assessment of U.S. and Chinese AI industries in the Tortoise Intelligence report confirms that the United States still maintains a strong advantage over China, its nearest competitor. Among the key areas of U.S. dominance are research, talent, and private funding. Nevertheless, China's heavy investment in AI, especially facial recognition technologies, has accelerated its growth, making it the fastest rising nation on the index scale, projected to match or surpass the United States in the next decade. Interestingly, both nations appear to depend on open-source coding and development platforms like Github. On key industrial strengths in AI, the report lays out the following:

- America's greatest strength is higher education, and its AI specialty is defense. "For every $1 the government spends on AI-related grants, 43 cents goes to the Department of Defence on research ranging from group decision-making to disease identification and audio analytics."
- China's greatest strength is supercomputers, and its AI specialty is facial recognition. "Last year, 85% of patents for facial recognition technology were filed in China. That's 13 times more than the number of facial recognition patents in the US."[141]

Frost and Sullivan

In March 2020, Frost and Sullivan Shanghai released a comparison of U.S. and Chinese AI industry development. This report followed similar trends of casting the United States as the established leader in the field, with China as an emerging competitor. Summary findings are that China's AI development started late but is strong in applications and that AI is fundamentally driving China's economic transformation. On the other hand, the United States leads in technological capacity and implementation, and its policies are aimed at maintaining global leadership.[142]

In terms of rolling out new technology, the AI "National Team" and start-up unicorns lead China's AI enterprise. The "National Team" focuses on technology integration within application areas, while startup unicorns are more vertically embedded in application markets. However, the United States has many AI manufacturers and is strong in both hardware and software. Large manufacturers are integrated in all phases of AI industry rollout, with startup businesses spread throughout the foundational, technology, and application layers. [143]

Summary and Implications: SWOT Analysis

The conclusions of the previous AI assessments are presented in Table 13, focusing on the relative strengths and weaknesses of China's AI ecosystem. These strengths and weaknesses inform opportunities for and threats to the United States in future AI competition. Because this research monograph focuses on China's AI ecosystem as an emerging competitor to the U.S. AI ecosystem, Table 13 presents a hybrid Strength-Weakness-Opportunity-Threat (SWOT) chart that pairs China's strengths and weaknesses against the opportunities and threats these pose to the United States.

China's heavy government involvement in AI development is a double-edged sword. On the one hand, clear strategies and focus on measurable goals have helped propel the Chinese AI industry to second place in the world. On the other hand, a metrics-driven approach can lead to favoring quantity over quality. China's success in quantity is visible in total academic papers and patents, as well as in adoption rates. However, some Chinese businesses possibly claim to be using AI tools just to add their names to national roles and give the appearance of supporting national goals. For these reasons and more, the U.S. free-market-driven AI industry is widely viewed as being more robust and sustainable.

Table 13: SWOT Analysis of China-U.S. Competition in AI

Strengths of China	Weaknesses of China
• Strong government support for AI • Robotics and automation • Supercomputers • Thriving research communities and AI innovation zones • Adoption across industries with AI+X concept • Focused on patenting new innovations • Fast-growing AI research base • Vast market and urban population • Access to and collection of data	• Attracting and retaining top AI talent • Semiconductor fabrication • Government-driven industries • Private venture capital declining • Dependence on international supply chains and open-source platforms, e.g. Github • Metrics-driven AI industry may value quantity over quality • Lack of diversity in AI workforce • Brain drain as top talent pursues graduate school in United States
Opportunities for United States	**Threats to United States**
• Increase international AI investments to capitalize on innovations outside United States • Untapped industrial and commercial areas for AI applications • Large network of allies and partners prefer U.S. technology • Leverage defense research to stimulate AI crossover to other sectors • Control access to critical supply chains and open-source systems upon which China relies	• Increasingly restrictive visa policies for students and researchers • Culture of open sharing for code and algorithms • Expanding employment opportunities and incentives for AI researchers in China • Chinese technology pricing undercuts U.S. competitiveness internationally • China publishing more academic papers in Mandarin limits two-way knowledge exchange

The current diplomatic and trade tensions between the United States and China have highlighted supply chain and talent interdependencies. World-class semiconductor manufacturing has been "globalized to such a degree that no country, including the United States and China, can make leading AI chips via exclusively domestic supply chains."[144] China's semiconductor megaprojects should improve domestic manufacturing capacity, but the chips produced will not be competitive compared to industry standards. Similarly, talent can be viewed as an international supply chain. World-class research universities rely on international graduate students to continue moving forward in science and technology. COVID-19 has caused substantial disruption to the research sector broadly and acutely among international researchers.[145] If training and education are the supply chain for talent, then the talented personnel are a commodity in limited supply. China's booming market for AI R&D has not yet begun attracting large numbers of foreign researchers. Nevertheless, immigration policies are a serious concern for Ph.D.-level AI professionals. A study by CSET found that 44 percent of international Ph.D.s viewed immigration concerns as an important factor in deciding on post-Ph.D. employment.[146] This finding implies that restrictive immigration policies or challenging application procedures will deter some of the most qualified workers from pursuing permanent employment in the offending countries.

Table 13 highlights opportunities for the United States to maintain leadership in AI. One critical factor in future competition will be having a network of likeminded nations with which to collaborate and cooperate. Building America's network of international partners will strengthen supply chains for both critical components like semiconductors and talent to stimulate future innovations. These partnerships could also yield lower-cost AI products, enhancing market competitiveness against Chinese technologies.

Messaging is also important. Xi Jinping's rhetoric about the China dream, the rejuvenation of the Chinese people, and leading the world in AI by 2030 have measurably motivated his citizens to take action toward these goals. At the same time, China's state propaganda machine works non-stop to eliminate narratives that paint China in a negative light. The United States should not waste time attempting to go head-to-head against the Chinese narrative, but instead tell the American story. For example, more international messages about opportunities for women and immigrants in U.S. graduate schools and technology industry would promote the U.S. strengths of diversity and inclusion without directly conflicting with, or shining a light on, China's propaganda.

Finally, when comparing AI development between the United States and China, it is important to discuss defense and security applications. Despite significant investments in general AI technology, the Chinese authorities prefer applications that support social control, such as facial recognition, natural language processing, and censorship. Conversely, American defense researchers remain focused on international applications like humanitarian assistance and disaster relief. According to Nand Mulchandani, acting director of the Joint Artificial Intelligence Center at the Department of Defense at the time of his comments, the United States leads where it counts in AI.[147]

Appendix 1:
MIIT New Generation AI Innovation Key Task List

Following the AIDP's publication, MIIT released the Three-Year Action Plan for Promoting Development of a New Generation Artificial Intelligence Industry (2018–20) in December 2017. In November 2018, to clarify the goals of the action plan with specific task areas and research directions, MIIT released a "work plan for key projects for the development of the next generation of AI," which included the following task list organized by major directions, specific task areas, and reference examples.[148]

Table 14: 17 Key tasks from MIIT New Generation AI Innovation Key Task List and Work Plan

Direction	Specific Area	Reference Examples
1. Intelligent connected cars	Autonomous car control systems	Autonomous driving level
		Number of interventions/km
		Distance driven
		Intelligent environment sensors' field of view, range, resolution, etc.
		Independent decisionmaking, precise planning and control ability
		High-precision map data collection and service capabilities
		Number of supported vehicle types
		Support V2X application category and quantity
		Number of application scenarios that support autonomous driving
		Industrialization and application
		Other indicators
	Autonomous car smart chips	Support autopilot function tasks
		Visual information processing ability
		Performance/power consumption
		Autonomous instruction set/autonomous IP
		Delay per frame
		Safety
		Industrialization and application
		Other indicators

Direction	Specific Area	Reference Examples
1. Intelligent connected cars	Onboard communication systems	Vehicle V2X information network communication capability
		Car communication chip performance
		Support V2X application category and quantity
		Standard compliance
		Communication security capability
		Industrialization and application
		Other indicators
2. Intelligent service robots	Intelligent home service robots	Intelligent interaction ability
		Autonomy
		Intelligent service knowledge base scale and knowledge representation quality
		Safety
		Industrialization and application
		Other indicators
	Intelligent educational robots	Intelligent interaction ability
		Bionic motor ability
		Intelligent service knowledge base scale and knowledge representation quality
		Industrialization and application
		Other indicators
	Intelligent public service robots	Environmental awareness
		Autonomous obstacle avoidance
		Intelligent interaction ability
		Intelligent service knowledge base scale and knowledge representation quality
		Safety
		Industrialization and application
		Other indicators
	Intelligent specialty robots	IntelliSense
		Autonomous decisionmaking ability
		Human-machine collaboration ability
		Autonomous obstacle avoidance
		Autonomous navigation capability
		Reliability
		Industrialization and applications
		Other indicators
	Intelligent surgeon robots	3D imaging and positioning
		Intelligent, precise, and safe control capability
		Human-machine collaboration ability
		Reliability
		Industrialization and application
		Other indicators
	Intelligent customer service robots	Business scenario coverage
		Intent recognition accuracy
		User problem-solving rate

Direction	Specific Area	Reference Examples
2. Intelligent service robots	Intelligent customer service robots	Knowledge base size and knowledge representation quality
		Number of large-scale deployment cases/number of processed conversations
		Other industrialization and application situations
		Other indicators
3. Intelligent unmanned aerial vehicles	Intelligent unmanned aerial vehicles	Perceived obstacle avoidance
		Stabilize gimbal accuracy
		Ability to automatically avoid air traffic control areas
		Intelligent cluster operation capability
		Data transmission communication rate
		Industrialization and application
		Other indicators
4. Medical imaging diagnostic support systems	Medical imaging diagnostic support systems	Detection rate of typical diseases
		False negative rate of typical diseases
		False positive rate of typical diseases
		Amount of clinical imaging data available in system
		Industrialization and application
		Other indicators
5. Video image identification systems	Video surveillance security identification systems	Effective detection rate of face recognition in complex dynamic scenes
		Scale of registration set supported by 1:N face recognition in complex dynamic scenarios
		Correct recognition rate in complex dynamic scenes (1:N)
		Support facial feature recognition in different regions
		Support gait recognition and other recognition methods
		System response time
		Industrialization and application
		Other situations
	Intelligent edge facial recognition systems	Effective detection rate of face recognition in complex dynamic scenes
		Correct recognition rate in complex dynamic scenarios
		Support facial feature recognition in different regions
		System resource usage
		System response time
		Living body detection/anti-attack capability
		Industrialization and application
		Other situations
6. Intelligent voice interaction systems	Intelligent voice interaction systems	Average accuracy/recall rate of Chinese speech recognition in multiple scenarios
		5m far-field recognition rate
		Accuracy of user dialogue intention recognition under multiple rounds of dialogue
		Supported international languages/minority languages/dialects
		Wake-up rate/false wake-up rate
		Average response time
		Invocation service satisfaction and accurate recommendation ability
		Cross-device experience of same household users

Direction	Specific Area	Reference Examples
6. Intelligent voice interaction systems	Intelligent voice interaction systems	Industrialization and application
		Other indicators
7. Intelligent language translation systems	Intelligent language translation systems	Language pairs that support intelligent mutual translation
		Product translation accuracy rate in Chinese-English and English-translation scenarios
		Accuracy of intelligent mutual translation between minority languages and Chinese
		Translation response time
		Maximum concurrent translation
		Support status and accuracy of offline translation
		Translation accuracy rate under voice/image input
		Readability (fluency)
		Daily requests
		Other industrialization and application situations
		Other indicators
8. Intelligent home appliance systems	Intelligent safety and security	Comprehensive perception and recognition of multiple environmental factors
		Intelligent danger warning capability
		Terminal data computing capability
		Cloud massive data processing capabilities
		Safety
		Industrialization and application
		Other indicators
	Intelligent home electronics	Embedded smart sensor components, quantity and type (body sensor, microphone, etc.)
		Embedded smart chip, quantity, and type
		Intelligent interaction ability
		Provide personalized intelligent service capabilities through learning
		Intelligent management ability
		Intelligent failure prediction capability
		Safety
		Industrialization and application
		Other indicators
9. Smart sensors	Smart sensors	Sensitivity
		Precision
		Resolution
		Degree of intelligent processing of data on sensor end (edge processing)
		Power consumption
		Industrialization and application
		Other indicators
10. Neural network chips	Cloud neural network chips	Number and categories of mainstream neural network algorithms supported
		Performance (16-bit floating point)
		Performance/power consumption

Direction	Specific Area	Reference Examples
10. Neural network chips	Cloud neural network chips	Autonomous instruction set /autonomous IP
		High-performance inter-chip interconnection
		Industrialization and application
		Other indicators
	Edge neural network chips	Number and categories of mainstream neural network algorithms supported
		Performance/power consumption (based on 16-bit floating point)
		Autonomous instruction set /autonomous IP
		Industrialization and application
		Other indicators
11. Open source, open platforms	Open source, open platforms	Large-scale distributed cluster parallel processing capabilities
		Support for different hardware platforms
		Support for multiple algorithm models, frameworks, and complex training tasks
		Number of active developers in the open-source community
		Type/number of applications that have been developed and provided services
		Number of data sets/number of models/number of users
		Application isolation method and developer experience
		Other indicators
12. Key technical equipment for intelligent manufacturing	Intelligent industrial robots	IntelliSense
		Human-machine collaboration ability
		Intelligent decision-making ability
		Flexible and precise control capability
		Abnormal situation handling ability
		Remote operation and maintenance capabilities
		Openness and secondary development capability
		Industrialization and application
		Other indicators
	Intelligent control equipment	IntelliSense
		Intelligent decision-making ability
		Intelligent and precise control ability
		Industrialization and application
		Other indicators
	Intelligent testing equipment	Industrial field visual recognition accuracy
		Measurement accuracy
		Processing speed
		Industrialization and application
		Other indicators
	Intelligent logistics equipment	Positioning method and accuracy
		Cargo classification processing capacity
		Human-machine collaboration level
		Movement route planning ability
		Sensitive obstacle avoidance

Direction	Specific Area	Reference Examples
12. Key technical equipment for intelligent manufacturing	Intelligent logistics equipment	Operating cost reduction rate after large-scale application
		Labor cost reduction rate after large-scale application
		Industrialization and application
		Other indicators
13. Repository of industry training resources	Repository of industry training resources	Data type/data volume
		Industries served
		Scale and accuracy of marked data
		Diversity of data distribution
		Opening and application situation
		Other indicators
14. Standard testing and intellectual property service platform	Standard testing and intellectual property service platform	AI standard service capabilities
		AI product evaluation capabilities
		AI industry intellectual property public service capabilities
		Standard testing and intellectual property services
		Other indicators
15. Intelligent network infrastructure	Raising the level of intelligentization of 4G/5G network infrastructure	Deployed network scale and number of nodes
		4G/5G average broadband access rate and delay
		Network performance tuning and parameter optimization intelligence level
		Intelligent sensing and monitoring capabilities of global network resources
		Network fault intelligent alarm, root cause location and self-healing capabilities
		Intelligent security assurance capabilities for equipment, network, emergency, etc.
		Platform service capabilities (API, etc.) that provide support for typical artificial intelligence applications such as autonomous driving, drones, robots, and big videos
		Number of typical AI applications supported
		Other demonstration applications
		Other indicators
	Industrial internet infrastructure to support industrial intelligentization applications	The scale of the deployed network and the number of nodes
		Logo resolution service capability
		The ability to provide services for new technology applications such as NB-IoT, IPv6, SDN/NFV, time sensitive network (TSN), edge computing, etc.
		Equipment, network, emergency, and other security assurance capabilities
		Demonstration applications
		Other indicators
	Network infrastructure to support networked vehicles	Deployed network size/coverage
		System capacity/connection density
		Two-way transmission rate and delay in typical application scenarios
		Support multiple communication standards
		Equipment, network, emergency, and other security assurance capabilities
		Demonstration applications
		Other indicators

Direction	Specific Area	Reference Examples
16. Network security assurance systems	AI security service platforms	Sample size of security vulnerability database, virus database, etc.
		Covering the types of smart products
		Safety detection, danger warning, and emergency response capabilities
		Status of external services
		Other indicators
	AI applications for network, information, and data security	Application of artificial intelligence technology improves safety detection capabilities
		Application of artificial intelligence technology improves security protection capabilities
		Application of artificial intelligence technology improves ability to identify and process vulgar and harmful information
		Application of artificial intelligence technology improves safe storage, transmission and processing of data
		Industrialization and application
		Other indicators
	AI edge security protection systems	AI edge security protection capability
		Main control APP security protection capability
		Private information leak protection capability
		Other metrics
17. Other directions	Other factor areas	Level of intelligentization
		Safety/security
		State of industry and application
		Industrialization and application

Source: Ministry of Industry and Information Technology, 新一代人工智能产业创新重点任务揭榜工作方案 [New Generation AI Innovation Key Task List and Work Plan], MIIT Announcement, 2018, no. 80, November 14, 2018, 17-24, http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c6489400/content.html.

Appendix 2:
100 AI Companies Contributing to New Infrastructure

This appendix lists the 100 companies associated with AI projects for "New Infrastructure" discussed in the chapter on China's AI Growth Strategy. Companies are organized by Chinese name (as shown in source), English name, and website (see Table 15).[149] Companies listed in bold text are New-Generation AI Open Innovation Platforms or members of the so-called National Team for AI (see Figure 2).

Table 15. 100 AI Companies Contributing to New Infrastructure

Index	Chinese Name	English Name	Website
1	**阿里巴巴**	**Alibaba**	**www.alibaba.com**
2	**百度**	**Baidu**	**www.baidu.com**
3	**腾讯**	**Tencent**	**www.tencent.com**
4	**华为**	**Huawei**	**www.huawei.com**
5	**科大讯飞**	**iFlyTek**	**www.iflytek.com**
6	华大基因	BGI	www.genomics.cn
7	**海康威视**	**Hikvision**	**www.hikvision.com**
8	蚂蚁金服	Ant Financial	www.antfin.com
9	字节跳动	ByteDance	www.bytedance.com
10	**京东**	**Jingdong**	**www.jd.com**
11	大疆创新	DJI	www.dji.com
12	**小米**	**Xiaomi**	**www.mi.com**
13	中科曙光	Sugon	www.sugon.com
14	网易	NetEase	www.163.com
15	搜狗	Sogou	www.sogou.com
16	浪潮	Inspur	en.inspur.com
17	**商汤科技**	**Sensetime**	**www.sensetime.com**

Index	Chinese Name	English Name	Website
18	寒武纪科技	Cambricon	www.cambricon.com
19	**旷视科技**	**Megvii**	**www.megvii.com**
20	四维图新	NavInfo	www.navinfo.com
21	思必驰	AISpeech	www.aispeech.com
22	**依图科技**	**Yitu**	**www.yitutech.com**
23	高德地图	AMap	lbs.amap.com
24	汉王科技	Hanvon	www.hw99.com
25	比特大陆	Bitmain	www.bitmain.com
26	优必选	UBTech	www.ubtrobot.com
27	地平线机器人	Horizon Robotics	horizon.ai
28	云从科技	Cloudwalk	www.cloudwalk.cn
29	云知声	Unisound	www.unisound.com
30	儒博科技	Roobo	www.roobo.com
31	中星微电子	Vimicro	www.vimicro.com
32	数据堂	Datatang	www.datatang.com
33	触景无线	Sensecape	www.sensecape.com.cn
34	捷通华声	SinoVoice	www.sinovoice.com
35	格灵深瞳	DeepGlint	www.deepglint.com
36	特斯联	Terminus	www.tslsmart.com
37	奥比中光	Orbbec	www.orbbec.com.cn
38	声智科技	SoundAI	www.soundAI.com
39	智臻智能	(Owner of) Xiao-i	www.xiaoi.com
40	出门问问	Mobvoi	www.chumenwenwen.com
41	Video++	Video++	videojj.com
42	Momenta	Momenta	www.momenta.cn
43	禾赛科技	Hesai Technology	www.hesaitech.com
44	智融集团	SmartFinance	www.smartfinancegroup.com
45	思派网络	MedBanks	www.medbanks.cn
46	影谱科技	MovieBook	www.moviebook.cn
47	虹软	ArcSoft	www.arcsoft.com.cn
48	海致BDP	BDP	www.bdp.cn
49	西井科技	Westwell Lab	www.westwell-lab.com
50	禾多科技	Holomatic	www.holomatic.cn
51	第四范式	4Paradigm	www.4paradigm.com
52	云天励飞	Intellifusion	www.intellif.com
53	人智科技	Shanghai PT Info Co.	www.ptinfous.com

Index	Chinese Name	English Name	Website
54	零零无线科技	ZeroZero Robotics	zerozero.tech
55	亮台风	HiAR	www.hiscene.com
56	物灵科技	Ling Technology	ling.cn
57	图森未来	TuSimple	www.tusimple.com
58	新松机器人	Siasun	www.siasun.com
59	速感科技	QfeelTech	www.qfeeltech.com
60	新石器	Neolix	www.neolix.cn
61	纵目科技	ZongMuTech	www.zongmutech.com
62	阅面科技	ReadSense	www.readsense.cn
63	小鱼在家	Ainemo	www.zaijia.com
64	MINIEYE	MINIEYE	www.minieye.cc
65	森亿智能	Synyi AI	www.synyi.com
66	**明略科技**	**Mininglamp Technology**	**www.mininglamp.com**
67	中天微	C-Sky Microsystems (bought by Alibaba Group)	github.com/c-sky/buildroot/releases
68	全志科技	Allwinner Technology	www.allwinnertech.com
69	碳云智能	iCarbonX	www.icarbonx.com
70	思岚科技	Slamtec	www.slamtec.com
71	瑞为科技	Revany (or Reconova)	www.raveny.com (reconova.com)
72	海运数据	Hydata	www.hydata.cc
73	中科创达	Thundersoft	www.thundersoft.com
74	翼展科技	Wingspan	www.wingspan.cn
75	速腾聚创	Robosense	www.robosense.cn
76	量化派	Quant Group	www.quantgroup.cn
77	远鉴科技	Fosafer	www.fosafer.com
78	智行者科技	iDriverPlus	www.idriverplus.com
79	云洲智能	Yunzhou	www.yunzhou-tech.com
80	神州泰岳	Ultrapower	www.ultrapower.com.cn
81	柏惠维康	Remebot	www.remebot.com.cn
82	深思考人工智能	iDeepWise	www.ideepwise.ai
83	小马智行	Pony.ai	www.pony.ai
84	冰鉴科技	IceKredit	www.icekredit.com
85	陌上花科技 Yi+	Yi+	www.dressplus.cn
86	图灵机器人	Turing Robot	www.turingapi.com
87	耐能人工智能	Kneron	www.kneron.com
88	深睿医疗	Deepwise	www.deepwise.com

Index	Chinese Name	English Name	Website
89	Geek+	Geek+	www.geekplus.com
90	图玛深维	12Sigma Technologies	tumashenwei.langye.net
91	布丁机器人	Pudding Robot (Roobo)	www.roobo.com
92	三角兽科技	Tricorn	www.trio.ai
93	汇医慧影	HY Medical	www.huiyihuiying.com
94	普强信息	Pachira	www.pachira.cn
95	推想科技	Infervision	www.infervision.com
96	驭势科技	Uisee	www.uisee.com
97	中科慧眼	SmarterEye	www.smartereye.com
98	Gowild 狗尾草	Gowild	www.gowild.cn
99	眼擎科技	Eyemore	www.eyemore.ai
100	GEO集奥聚合	GEO	www.geotmt.com

Source: "619家 "新基建" 重点目标企业名单 [Roster of 619 Enterprises Supporting "New Infrastructure" Key Objectives]," 5G Industry Circle, June 21, 2020, http://www.rzweiqi.com/third_1.asp?txtid=36.

Endnotes

1. *National Security Strategy of the United States*, The White House, December 2017, 27, https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.
2. Joint Staff, *Description of the National Military Strategy,* Directorate for Strategy, Plans, and Policy (J-5), 2018, https://www.jcs.mil/Portals/36/Documents/Publications/UNCLASS_2018_National_Military_Strategy_Description.pdf.
3. Michael Kratsios, "U.S. Tech Leadership in an Era of Competition," Question and Answer session (accessed in embedded video, 22:35-22:47), Center for Security and Emerging Technology, Georgetown University, August 13, 2020, https://cset.georgetown.edu/event/u-s-tech-leadership-in-an-era-of-competition/.
4. Eric Schmidt, "An AI National Strategy for Congress," Bipartisan Policy Center (webcast), August 25, 2020, https://www.youtube.com/watch?v=JZcCwfkZIMQ.
5. Katie Costello, "Gartner Says AI Augmentation Will Create $2.9 Trillion of Business Value in 2021," Gartner, August 5, 2019, https://www.gartner.com/en/newsroom/press-releases/2019-08-05-gartner-says-ai-augmentation-will-create-2point9-trillion-of-business-value-in-2021.
6. Thomas J. Colvin et al., *A Brief Examination of Chinese Government Expenditures on Artificial Intelligence R&D*, Science & Technology Policy Institute, Institute for Defense Analysis, February 2020, 5.
7. Rose Tenyotkin et al., *Economic Statecraft: How China Legally Accesses Foreign Technologies to Build Military Capabilities*, CNA Research Memorandum, June 2020, i.
8. State Council, *The National Medium- and Long-Term Program for Science and Technology Development (2006-2020): An Outline*, People's Republic of China, 8, https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf
9. State Council, *The National Medium- and Long-Term Program*, 40-45.
10. "China Plans To Open Wider in Science, Technology," *Xinhua* (online), December 4, 2006, accessed September 13, 2019, http://www.gov.cn/english/2006-12/04/content_460484.htm.
11. Ministry of Science and Technology, 十二五国际科技合作的思路和目标 [12th Five-Year Plan Thoughts and Objectives for International Science and Technology Cooperation], People's Republic of China, August 26, 2011, www.most.gov.cn/ztzl/qgkjwsgzhy/kjwszwsew/201108/t20110826_89286.htm. [Selected text: 开放中创新，在合作中共赢，充分发挥国际科技合作对国家科技发展的促进和推动作用，不断扩大我国科技对外影响and着力建设国际化人才队伍，充分利用海外科技人才加快提升自主创新能力.]
12. Derek Adam Levine, "Made in China 2025: China's Strategy for Becoming a Global High-Tech Superpower and its Implications for the U.S. Economy, National Security, and Free Trade," *Journal of Strategic Security* 13, no. 3 (2020): 5, https://doi.org/10.5038/1944-0472.13.3.1833.
13. 十三五国家科技创新规划 [13th Five-Year Science and Technology Innovation Plan], People's Republic of China, July 28, 2016, http://www.gov.cn/gongbao/content/2016/content_5103134.htm.
14. 13th Five-Year Science and Technology Innovation Plan, Chapter 3, Section 6.
15. Probably Cornell University's Global Innovation Index, due to agreement between the index's 2015 ranking for China and that cited in the STIP. Soumitra Dutta et al., *The Global Innovation Index 2015: Effective Innovation*

Policies for Development, Cornell University, https://www.globalinnovationindex.org; INSEAD; World Intellectual Property Organization, 2015, https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2015-chapter1.pdf.

16. Soumitra Dutta, Bruno Lanvin, and Sacha Wunsch-Vincent, *Global Innovation Index 2019*, Cornell University, https://www.globalinnovationindex.org; INSEAD; World Intellectual Property Organization, 2019, https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2019.pdf.
17. Facts and Figures, World Intellectual Property Organization, 2019, https://www.wipo.int/edocs/infogdocs/en/ipfactsandfigures2019/.
18. State Council, "State Council Notice on the Issuance of *New Generation Artificial Intelligence Development Plan*," 2017, http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm.
19. Department of International Cooperation, Ministry of Science and Technology, "Next Generation Artificial Intelligence Development Plan Issued by State Council," China Science & Technology Newsletter, No. 17, September 15, 2017.
20. Zhao Yongxin, 科技创新2030—重大项目启动 [Science and Technology Innovation 2030 – Major Projects Kick Off], *People's Daily*, February 20, 2017, http://www.gov.cn/xinwen/2017-02/20/content_5169236.htm.
21. China Innovation Funding, "'2030 Megaproject'—New Generation Artificial Intelligence (2018 Annual Call)," http://chinainnovationfunding.eu/project/2030-megaproject-new-generation-artificial-intelligence/.
22. Saif M. Khan, *AI Chips: What They Are and Why They Matter*, Center for Security and Emerging Technology, Georgetown University, April 2020, https://cset.georgetown.edu/research/ai-chips-what-they-are-and-why-they-matter/.
23. Fei Wu et al., "Towards a New Generation of Artificial Intelligence in China," *Nature Machine Intelligence,* 2 (June 2020): 312-16, https://doi.org/10.1038/s42256-020-0183-4.
24. Huw Roberts et al., "The Chinese Approach to Artificial Intelligence: An Analysis of Policy and Regulation," *Social Science Research Network*, September 1, 2019, 4, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3469784.
25. Meng Jing, "China To Boost Its 'National Team' To Meet Goal of Global AI Leadership by 2030," *South China Morning Post*, November 15, 2018, https://www.scmp.com/tech/innovation/article/2173345/china-boost-its-national-team-meet-goal-global-ai-leadership-2030.
26. Ministry of Information and Industry Technology, 新一代人工智能产业创新重点任务揭榜工作方案 [New Generation AI Innovation Key Task List and Work Plan], People's Republic of China, MIIT Announcement, no. 80, November 14, 2018, 17-24, http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c6489400/content.html.
27. "2019 AI Development White Paper" (slide show), Chinese Academy of Sciences Key Laboratory for Big Data Mining and Knowledge Management, February 2020, 29, accessed through https://ChinAI.substack.com, slides available at https://drive.google.com/file/d/1_WQ3WcZxVEf2_KoAcsPYT9PE_uWtdyPV/view.
28. English translation available from Center for Security and Emerging Technology, Georgetown University, at https://cset.georgetown.edu/research/ministry-of-science-and-technology-notice-on-the-publication-of-the-guidance-on-national-new-generation-artificial-intelligence-open-innovation-platform-construction-work/.
29. 2019年国家新一代人工智能开放创新平台 建设情况：人工智能 "国家队" 从5家扩充至15家 [2019 Update on Establishing National New Generation AI Open Innovation Platforms: AI "National Team" Expands From 5 to 15 Members], Qianjia.com, September 17, 2019, http://www.qianjia.com/html/2019-09/17_350266.html, Note site referenced source 前瞻产业研究院发布的《中国人工智能行业市场前瞻与投资战略规划分析报告》[Foresight Manufacturing Research Institute "Analysis Report on China AI Industry Market Outlook and Investment Strategic Plans"], https://bg.qianzhan.com/.
30. China Innovation Funding, "Work Guidelines for the Construction of New Generation Artificial Intelligence Open Innovation Platforms," People's Republic of China, http://chinainnovationfunding.eu/dt_testimonials/work-guidelines-for-the-construction-of-new-generation-artificial-intelligence-open-innovation-platforms/.

31. Catherine Shu, "Eight Chinese Tech Firms Placed on US Entity List for Their Role in Human Rights Violations Against Muslim Minority Groups," *TechCrunch*, October 8, 2019, https://techcrunch.com/2019/10/07/eight-chinese-tech-firms-placed-on-u-s-entity-list-for-their-role-in-human-rights-violations-against-muslim-minority-groups/.
32. Communist Party of China, "Central Economic Working Conference," People's Republic of China, http://www.12371.cn/special/lczyjjgzhy/.
33. China Center for Information and Industry Development, "新基建" 政策白皮书 ["New Infrastructure" Policy White Paper], Policy and Regulation Research Center and Industrial Policy Research Center, [in Chinese], People's Republic of China, April 21, 2020, http://www.cbdio.com/BigData/2020-04/21/content_6155699.htm.
34. National Development and Reform Commission, 国家首次官宣"新基建"范围：3大方面，7大领域 [China Makes First Official Announcement on the Scope of "New Infrastructure": 3 Major Components, 7 Main Areas], People's Republic of China, June 13, 2020, http://www.rzweiqi.com/third_1.asp?txtid=13.
35. Offbeat, "Why This Country Has Over 50 Ghost Cities," *NDTV*, May 3, 2019, https://www.ndtv.com/offbeat/why-china-has-over-50-ghost-cities-2032322.
36. Pei Li, "Tencent to Invest $70 Billion in 'New Infrastructure,'" *Reuters*, May 26, 2020, https://www.reuters.com/article/us-tencent-cloud-investment-idUSKBN2320VB.
37. China Center for Information and Industry Development, 2020 城市新基建布局与发展白皮书 [2020 White Paper for City-level "New Infrastructure" Deployment and Development], People's Republic of China, April 2020, http://www.cbdio.com/BigData/2020-05/19/content_6156378.htm.
38. 619家"新基建"重点目标企业名单 [Roster of 619 Enterprises Supporting "New Infrastructure" Key Objectives], 5G Industry Circle, June 21, 2020, http://www.rzweiqi.com/third_1.asp?txtid=36.
39. State Council, 《新时代的中国国防》白皮书全文 [2019 Defense White Paper: "China's National Defense in the New Era"], People's Republic of China, July 24, 2019, http://www.81.cn/jmywyl/2019-07/24/content_9567323.htm.
40. Andrew Erickson, *Full Text of 2019 Defense White Paper: "China's National Defense in the New Era,"* July 24, 2019, https://www.andrewerickson.com/2019/07/full-text-of-defense-white-paper-chinas-national-defense-in-the-new-era-english-chinese-versions/.
41. Rogier Creemers et al., "Xi Jinping's Sept. 2020 Speech on Science and Technology Development (Translation)," New America, September 22, 2020, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/translation-xi-jinpings-sept-2020-speech-science-and-technology/.
42. Xi Jinping, 习近平：在科学家座谈会上的讲话 [Xi Jinping: Speech at Scientists' Forum], *Xinhua*, September 11, 2020, www.xinhuanet.com/politics/2020-09/11/c_1126483997.htm.
43. Katie Costello, "Gartner Says AI Augmentation Will Create $2.9 Trillion of Business Value in 2021," Gartner, August 5, 2019, https://www.gartner.com/en/newsroom/press-releases/2019-08-05-gartner-says-ai-augmentation-will-create-2point9-trillion-of-business-value-in-2021.
44. Department of International Cooperation, Ministry of Science and Technology, "China's Strengths Creates Innovation Miracles," *China Science & Technology Newsletter,* No. 17, September 18, 2017.
45. 天文在线 [Astronomy Online], 两下一上，中国发射首次火星探测任务。下一步，NASA [Two Down and One to Go, China Launches Its First Mars Exploration Mission. Next, NASA], Sina, July 25, 2020, https://k.sina.com.cn/article_1808449333_6bcabf3502700qqgv.html.
46. Jeffrey Ding, "ChinAI #82: State Grid—A Hidden Giant in AI?," *ChinAI Newsletter*, February 9, 2020, https://chinai.substack.com/p/chinai-82-state-grid-a-hidden-giant.
47. "Marijuana Electricity Consumption," GreenCulturED, March 3, 2020, https://www.greencultured.co/marijuana-electricity-consumption/.

48. Carrick Flynn and Saif Khan, *Multilateral Controls on Hardware Chokepoints*, Center for Security and Emerging Technology (CSET), Georgetown University, September 2020, https://cset.georgetown.edu/research/multilateral-controls-on-hardware-chokepoints/.
49. Greg Levesque, "Here's How China Is Achieving Global Semiconductor Dominance," *The National Interest*, June 25, 2018, https://nationalinterest.org/feature/heres-how-china-achieving-global-semiconductor-dominance-26402.
50. 2020年国内双一流大学排行榜，榜首名副其实，复旦逆袭为第三 [2020 List of Double First Class Universities, First Place Is Worthy of the List, Fudan Strikes Back as Number Three], *Tencent QQ*, October 17, 2020, https://new.qq.com/rain/a/20201017A0A3KV00.
51. 全国双一流大学名单及双一流学科名单汇总（42所一流大学+95所一流学科建设高校）[Complete List of Chinese Double First Class Universities and Double First Class Disciplines (42 First Class Universities + 95 First Class Discipline Construction Schools], 大学生必备 [College Student Necessities], August 6, 2020, https://www.dxsbb.com/news/43247.html.
52. 无忧文案 [Worry-free Copywriting], 继'双一流'之后，教育部又有1重大计划发布! [Ministry of Education Announces Another Major Plan To Follow 'Double First Class'], *Baidu Blog*, April 10, 2019, https://baijiahao.baidu.com/s?id=1630345503499312627&wfr=spider&for=pc.
53. 汤晓鸥 and 陈玉琨 [Tang Xiao'ou and Chen Yukun, eds.], 人工智能基础(高中版) [Fundamentals of Artificial Intelligence (High School Edition)] (Eastern China Normal University Publishing, Shanghai, 2018).
54. 广问AI [Guangwen AI], 人工智能课程今秋进入高中 北京多所学校已经先行一步 [AI Curriculum Enters High Schools This Fall, Many Schools in Beijing Have Already Taken First Steps], May 5, 2019, https://www.sohu.com/a/311883342_545815.
55. 优质创 [You Zhichuang], 教育部通知：35所高校增加人工智能专业，2019高考学生可以报考 [Notice From Ministry of Education: 35 Universities Add AI Majors, Students Taking the 2019 National Higher Education Entrance Examination Can Apply], 教育世界博览 [Education World Expo], March 30, 2019, https://baijiahao.baidu.com/s?id=1629402196792730665.
56. CSrankings, queried October 5, 2020, http://csrankings.org/#/fromyear/2015/toyear/2020/index?ai&vision&mlmining&nlp&ir&asia.
57. Synced, "China's AI Schools Are Accepting Applications: Here's a List," *Medium*, June 30, 2018, https://medium.com/syncedreview/chinas-ai-schools-are-accepting-applications-here-s-a-list-5a568e1e31a1.
58. Prashant Loyalka et al., "Computer Science Skills Across China, India, Russia, and the United States," Proceedings of the National Academy of Sciences of the United States (PNAS), April 2, 2019, https://www.pnas.org/content/116/14/6732.
59. Tina Huang and Zachary Arnold, *Immigration Policy and the Global Competition for AI Talent*, Center for Security and Emerging Technology (CSET), Georgetown University, June 2020, iii.
60. State Council, *Defense White Paper: "China's National Defense in the New Era,"* [in Chinese], People's Republic of China, 2019, http://www.81.cn/jmywyl/2019-07/24/content_9567323.htm.
61. 全国双一流大学名单及双一流学科名单汇总（42所一流大学+95所一流学科建设高校）[Complete List of Chinese Double First Class Universities and Double First Class Disciplines (42 First Class Universities + 95 First Class Discipline Construction Schools], 大学生必备 [College Student Necessities], August 6, 2020, https://www.dxsbb.com/news/43247.html.
62. Kai-Fu Lee, *AI Superpowers: China, Silicon Valley, and the New World Order* (Boston: Houghton Mifflin Harcourt, 2018).
63. China Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control*, Version 1.0, People's Republic of China, March 2020.
64. 刘刚 [Liu Gang], 中国新一代人工智能科技产业法山报告 (2019) [China's New-Generation Artificial Intelligence Technology Industry Development Report (2019)], Presented at the closing ceremonies of the 3rd World AI

Conference, slides posted at http://www.sohu.com/a/318567654_740319, from source: 人工智能和大数据 [AI and Big Data], slide 3.

65. 深圳前瞻产业研究院 [Shenzhen Forward Industry Research Institute], 2019年人工智能行业现状与 发展趋势报告 [2019 Report on AI Industry Situation and Development Trends], September 2019, 21, http://www.cbdio.com/image/site2/20191009/f42853157e261f07cc5719.pdf.
66. 钟源 [Zhong Yuan], 新一代人工智能创新发展试验区 扩至12市一县 [New Generation AI Innovation Development Experimental Zones Expand to 12 Cities and One County], 经济参考报 [Economic Reference Report], September 9, 2020, http://www.cbdio.com/BigData/2020-09/09/content_6160020.htm.
67. Frost & Sullivan Shanghai, 一文了解中美AI产业布局：一个"行业霸主"，一个"新晋强者" [Chinese and American AI Industry Roll-out: One an "Industry Hegemon", One a "New Powerhouse"], March 30, 2020, http://www.cbdio.com/BigData/2020-03/30/content_6155329.htm.
68. The US-China Business Council, "National Development and Reform Commission," 2018, 1, https://www.uschina.org/sites/default/files/2018.12.28_ndrc.pdf.
69. The US-China Business Council, "National Development and Reform Commission," 5.
70. Original CSET Translation of 国务院关于印发"十三五"国家战略性新兴产业发展规划的通知 [National "13th Five-Year" Plan for the Development of Strategic Emerging Industries], Central People's Government of the People's Republic of China, November 29, 2016, https://cset.georgetown.edu/research/national-13th-five-year-plan-for-the-development-of-strategic-emerging-industries/.
71. CAICT, 人工智能实力白皮书 [AI Governance White Paper], joint work by China Academy of Information and Communication Technology and China Artificial Intelligence Industry Alliance, September 2020, 19.
72. Theresa Hitchens, "NatSec AI Commission Urges New Vice Prez-Led Council," *Breaking Defense*, October 13, 2020, https://breakingdefense.com/2020/10/natsec-ai-commission-urges-new-vice-prez-led-council/.
73. 梁福龙 [Liang Fulong], 新一代人工智能发展规划推进办公室成立, 建设四大国家级开放创新平台 [New Generation AIDP Advancement Office Established, Names Four National Open Innovation Platforms], Guancha.com, November 17, 2017, https://www.guancha.cn/Industry/2017_11_17_435296.shtml.
74. Thomas J. Colvin et al., *A Brief Examination of Chinese Government Expenditures on Artificial Intelligence R&D*, Science & Technology Policy Institute, Institute for Defense Analysis, February 2020, 31-33.
75. Ashwin Acharya and Zachary Arnold, *Chinese Public AI R&D Spending: Provisional Findings*, Center for Security and Emerging Technology, Georgetown University, December 2019, 13, https://cset.georgetown.edu/research/chinese-public-ai-rd-spending-provisional-findings/.
76. SCMP Research, "China AI Report 2020," *South China Morning Post*, February 2020, 12.
77. Field Cady and Oren Etzioni, "China May Overtake US in AI Research," *Medium AI-2 Blog*, Allen Institute for Artificial Intelligence, March 13, 2019, https://medium.com/ai2-blog/china-to-overtake-us-in-ai-research-8b6b1fe30595.
78. Scimago Journal and Country Rank, accessed January 29, 2021, https://www.scimagojr.com/journalrank.php?category=1702.
79. Alexander Hammer and Shahid Yousef, "Is China in a High-Tech, Low Productivity Trap?" Office of Economics Working Paper 2020–07–B, US International Trade Commission, 12.
80. Paul Mozur and Cade Metz, "A U.S. Secret Weapon in A.I.: Chinese Talent," *New York Times*, June 9, 2020, https://www.nytimes.com/2020/06/09/technology/china-ai-research-education.html. Full talent tracker tool available at https://macropolo.org/digital-projects/the-global-ai-talent-tracker/.
81. Wm. C. Hannas and Huey-meei Chang, *China's Access to Foreign AI Technology*, Center for Security and Emerging Technology, Georgetown University, September 2019, https://cset.georgetown.edu/wp-content/uploads/CSET-Chinas-Access-to-Foreign-AI-Technology-2.pdf..

82. 刘刚 [Liu Gang], 中国新一代人工智能科技产业法山报告 (2019) [China's New-Generation Artificial Intelligence Technology Industry Development Report (2019)], Presented at the closing ceremonies of the 3rd World AI Conference, slides posted at http://www.sohu.com/a/318567654_740319, from source: 人工智能和大数据 [AI and Big Data].
83. Chinese Association for Artificial Intelligence website, accessed December 19, 2019, www.caai.cn.
84. China Association for Science and Technology website, accessed September 23, 2020, http://english.cast.org.cn.
85. Rui Hu, "3rd Asian Conference on Artificial Intelligence Technology Held in Chongqing," *iChongqing*, July 10, 2019, https://www.ichongqing.info/2019/07/10/3rd-asian-conference-on-artificial-intelligence-technology-held-in-chongqing/.
86. Conference papers from ACAIT 2019 published in *Journal of Engineering*, ISSN 2051-3305.
87. Extended articles from ACAIT 2019 published in *IET Computer Vision*, ISSN 1751-9640, or *IET Image Processing*, ISSN 1751-9667.
88. CCF–China Computer Federation, *Springer*, www.springer.com/gp/computer-science/lncs/societies-and-lncs/ccf-china-computer-federation/734376.
89. Microsoft AI Lab, "Intelligent Robotics with AI," Microsoft Corporation, accessed January 5, 2021, https://www.microsoft.com/en-us/ai/ai-lab-intelligent-robotics.
90. China Computer Federation, CCF关于成立智能机器人专业组的公告 [Announcement on CCF Establishing Intelligent Robot Special Team], https://www.ccf.org.cn/c/2019-10-24/669593.shtml.
91. www.aiiaorg.cn, as cited by Graham Webster, "Translation: Chinese AI Alliance Drafts Self-Discipline 'Joint Pledge,'" (blog), June 17, 2019, www.newamerica.org/cybersecurity-initiative/digichina/blog/translation-chinese-ai-alliance-drafts-self-discipline-joint-pledge.
92. Jeffrey Ding, "ChinAI #89: 500+ Use Cases of AI in Coronavirus Control," *ChinAI Newsletter*, April 16, 2020, https://chinai.substack.com/.
93. "Beijing AI Principles," as posted on Xinhua, http://www.xinhuanet.com/english/2019-05/26/c_138091724.htm. and online at https://www.baai.ac.cn/news/beijing-ai-principles-en.html.
94. "AI Talents From Around the World Gather at the Qiantang River for the Zhejiang Lab Cup," ABNewsWire, October 29, 2019, www.zhejianglab.com.
95. As written on the National University of Singapore event page for the Zhejiang Lab Cup, accessed November 14, 2019, https://nus.edu.sg/cfg/events/2019-zhejiang-lab-cup-global-ai-competition.
96. "Li Wenliang," *The Lancet*, Obituary, February 18, 2020, https://doi.org/10.1016/S0140-6736(20)30382-2.
97. Gao Qiang, "SARS Prevention and Control in China," Presentation to the World Health Organization in Kuala Lumpur, June 17, 2003, 23-24, https://www.who.int/csr/sars/conference/june_2003/materials/presentations/en/sarschina170603.pdf.
98. China Academy of Information and Communications Technology, *Big Data White Paper (2019)*, People's Republic of China, December 2019, 33.
99. China Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control,* Version 1.0, People's Republic of China, March 2020, 2.
100. International Society for Infectious Diseases, "Undiagnosed Pneumonia—China (Hubei): Request for Information," *ProMED*, December 31, 2019, https://promedmail.org/promed-post/?id=6864153.
101. 武汉首例新冠肺炎发现时间 武汉肺炎第一例最早发现时间 [Time of Discovery for the First Case of Wuhan Novel Coronavirus, Time of Discovery for the Earliest Case of Wuhan Pneumonia], *Wuhan City Municipal News,* January 27, 2020, http://m.wuhan.com/mipw/xinwen/37914.html.
102. Chris Buckley and Paul Mozur, "A New Martyr Puts a Face on China's Deepening Coronavirus Crisis," *New York Times*, February 7, 2020, https://www.nytimes.com/2020/02/07/world/asia/china-coronavirus-doctor-death.html.
103. Louise Watt, "Taiwan Says It Tried to Warn the World About Coronavirus. Here's What It Really Knew and When," *Time*, May 19, 2020, https://time.com/5826025/taiwan-who-trump-coronavirus-covid19/.

104. COVID-19 Coronavirus Pandemic, Johns Hopkins University, Coronavirus Resource Center, December 16, 2020, https://coronavirus.jhu.edu/map.html. Population data accessed October 1, 2020 from https://www.worldometers.info/world-population/taiwan-population/.

105. China Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control,* Version 1.0, People's Republic of China, March 2020.

106. "Chinese People Stand United Against Pneumonia Outbreak," *People's Daily Online*, January 23, 2020, retrieved April 7, 2020, from http://en.people.cn/n3/2020/0123/c90000-9651528.html.

107. Xinhua News, "Commentary: China Firm To Win Anti-virus Battle at all Cost," *People's Daily Online,* January 27, 2020, retrieved March 26, 2020, from http://en.people.cn/n3/2020/0127/c90000-9651891.html.

108. Xinhua News Beijing, 坚定信心打赢疫情防控阻击战 [Absolute Resolve To Win the War Against the Outbreak], *PLA Daily*, January 26, 2020, retrieved from http://www.81.cn/jfjbmap/content/2020-01/26/content_252905.htm.

109. Ministry of Industry and Information Technology, 充分发挥人工智能赋能效用 协力抗击新型冠状病毒感染的肺炎疫情倡议书 [Initiatives To Fully Capitalize on Efficiencies of Artificial Intelligence and Collaborate To Combat the COVID-19 Outbreak], People's Republic of China, February 4, 2020, retrieved April 7, 2020, from http://www.miit.gov.cn/n1146290/n1146402/n1146440/c7664158/content.htm.

110. China Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control,* Version 1.0, People's Republic of China, March 2020, 35.

111. P. Chen, 支付宝：正研发全国统一的疫情防控健康码系统，下周上线 [Alipay: Developing Single Nation-wide Health Code System to Control the Epidemic, Going Online Next Week], *Beijing Economic News,* February 16, 2020, accessed March 26, 2020, https://baijiahao.baidu.com/s?id=1658668769961743345.

112. K. Kupferschmidt and J. Cohen, "China's Aggressive Measures Have Slowed the Coronavirus. They May Not Work in Other Countries," *Science,* March 2, 2020, accessed March 27, 2020, https://www.sciencemag.org/news/2020/03/china-s-aggressive-measures-have-slowed-coronavirus-they-may-not-work-other-countries.

113. Winston Ma Wenyan, "China Is Waking Up to Data Protection and Privacy. Here's Why That Matters," *World Economic Forum*, November 12, 2019, https://www.weforum.org/agenda/2019/11/china-data-privacy-laws-guideline.

114. Xinhua, "Commentary: Collectivism Plays Indispensable Role in China's COVID-19 Fight," *XinhuaNet News*, March 17, 2020, http://www.xinhuanet.com/english/2020-03/17/c_138888436.htm.

115. China Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control,* Version 1.0, People's Republic of China, March 2020, 44.

116. Chinese Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control*, 44.

117. Cybersecurity Administration of China, 关于做好个人信息保护利用大数据支撑联防联控工作的通知 [Notice on Doing a Good Job in Protecting Personal Information and Using Big Data to Support Joint Prevention and Control], People's Republic of China, February 9, 2020, http://www.cac.gov.cn/2020-02/09/c_1582791585580220.htm.

118. Chinese name 国家工业信息安全发展研究中心 translates to National Industrial Information Security Development Research Center, also known as Etiri, website: www.etiri.com.cn, phone: 010-88686171, address: Dianke Building 35 Lugu Rd, Shijingshan District, Beijing, 100040.

119. Chen Jinmei, ed., 大数据产品和解决方案服务能力目录指引 [Guidelines for the Big Data Product and Solutions Services List], Special COVID-19 Edition, China Industrial Control Systems Cyber Emergency Response Team, May 6, 2020, http://www.cbdio.com/BigData/2020-05/06/content_6156092.htm.

120. Synced, "Artificial Intelligence Solutions in Response to the COVID-19 pandemic–China–Database," *AI Against COVID-19 Vol I*, Synced Review, https://payhip.com/b/i5bN.

121. "Tencent AI Helps Hubei Hospitals Identify COVID-19 in One Minute," February 21, 2020, Tencent, https://www.tencent.com/en-us/articles/2200960.html.
122. Arjun Kharpal, "China's Giants From Alibaba to Tencent Ramp Up Health Tech Efforts To Battle Coronavirus," CNBC, March 3, 2020, https://www.cnbc.com/2020/03/04/coronavirus-china-alibaba-tencent-baidu-boost-health-tech-efforts.html.
123. Cheng Yu, "iFlytek Banking on AI To Fight Against Epidemic," *China Daily*, February 18, 2020, http://www.chinadaily.com.cn/a/202002/18/WS5e4b3e29a31012821727845e.html.
124. Chen Jinmei, ed., 大数据产品和解决方案服务能力目录指引 [Big Data Product and Solution Service Capability Directory Guide], Special COVID-19 Edition, China Industrial Control Systems Cyber Emergency Response Team, May 6, 2020, p. 9, http://www.cbdio.com/BigData/2020-05/06/content_6156092.htm.
125. Leiphone, 无人驾驶"抗疫联盟"赋能者，百度Apollo的台前与幕后 [Unmanned Driving 'Anti-epidemic Alliance' Enabler, Baidu Apollo in Front and Behind the Scenes], *Sina Tech*, March 24, 2020, https://tech.sina.com.cn/roll/2020-03-24/doc-iimxxsth1510732.shtml
126. AI Lab, 百度AI战疫五十天：三场战役与一次胜利 [Fifty Days of Baidu AI Fighting Epidemic: Three Battles and One Victory], People's Republic of China, March 19, 2020, http://www.ailab.cn/ai/2020031998009.html.
127. Synced, "Beijing to Open 100 Unmanned Taxi Stations," *Synced AI Technology & Industry Review*, October 19, 2020, https://syncedreview.com/2020/10/19/beijing-to-open-100-unmanned-taxi-stations/.
128. 发热门诊、AI测温、机器人巡逻...人工智能成山东战疫生力军 [Fever Consultation, AI Temperature Checks, Robot Patrols...AI Becomes a Force in the Battle Against Epidemic in Shandong], Qilu Evening News, March 10, 2020, accessed on March 26, 2020, https://baijiahao.baidu.com/s?id=1660703537815311829&wfr=spider&for=pc.
129. Artificial Intelligence Industry Alliance (AIIA), 人工智能助力新冠疫情防控调研报告 [Research Report on AI Assisting Epidemic Prevention and Control for COVID-19], People's Republic of China, March 2020, 3.
130. Synced, "Artificial Intelligence Solutions in Response to the COVID-19 pandemic–China–Database," *AI Against COVID-19 Vol I*, Synced Review, https://payhip.com/b/i5bN.
131. 济南市人工智能产业创新发展联盟成立 [Jinan Establishes Artificial Intelligence Industry Innovation and Development Alliance], Xinhua News Shandong, September 3, 2019, accessed on April 7, 2020, http://www.sd.xinhuanet.com/edu/2019-09/03/c_1124955875.htm.
132. 发热门诊、AI测温、机器人巡逻...人工智能成山东战疫生力军 [Fever Consultation, AI Temperature Checks, Robot Patrols...AI Becomes a Force in the Battle Against Epidemic in Shandong], Qilu Evening News, March 10, 2020, accessed on March 26, 2020, https://baijiahao.baidu.com/s?id=1660703537815311829&wfr=spider&for=pc.
133. Nadia Lam, "How China Claimed Victory Over the Coronavirus," *South China Morning Post*, November 12, 2020, https://www.scmp.com/news/china/society/article/3109393/how-china-claimed-victory-over-coronavirus.
134. 战疫一线报告: 疫情期间 人工智能怎么"大显神通" [Report From the Front Lines: How AI "Showed Its Magic" During the Epidemic], CCTV News, March 25, 2020, http://news.cctv.com/2020/03/25/ARTICpWp6AeOZIoy4DgceVYB200325.shtml.
135. China Academy of Information and Communications Technology, *Research Report on Data and Smart Applications for Epidemic Prevention and Control,* Version 1.0, People's Republic of China, March 2020, 51.
136. Daniel Castro, Michael McLoughlin, and Eline Chivot, *Who is Winning the AI Race: China, the EU, or the United States?,* Center for Data Innovation, August 2019.
137. Castro, McLoughlin, and Chivot, *Who is Winning the AI Race?,* 35.
138. Raymond Perrault et al., "The AI Index 2019 Annual Report," AI Index Steering Committee, Human-Centered AI Institute, Stanford University, Stanford, CA, December 2019, 4, https://hai.stanford.edu/sites/default/files/ai_index_2019_report.pdf.

139. Raymond Perrault et al., “The AI Index 2019 Annual Report,” 16-17.
140. Alexandra Mousavizadeh, Alexi Mostrous, and Alex Clark, “The Arms Race,” *The Global AI Index*, Tortoise Media, December 3, 2019, https://members.tortoisemedia.com/2019/12/03/global-ai-index/content.html.
141. Ella Hollowood, “Countries in Focus,” *The Global AI Index*, Tortoise Media, December 3, 2019, https://members.tortoisemedia.com/2019/12/03/global-ai-index-2-countries/content.html.
142. Frost & Sullivan Shanghai, 一文了解中美AI产业布局：一个“行业霸主”，一个“新晋强者” [Chinese and American AI Industry Roll-out: One an “Industry Hegemon”, One a “New Powerhouse”], Frost & Sullivan, March 30, 2020, http://www.cbdio.com/BigData/2020-03/30/content_6155329.htm.
143. Frost & Sullivan Shanghai, 一文了解中美AI产业布局：一个“行业霸主”，一个“新晋强者” [Chinese and American AI Industry Roll-out: One an “Industry Hegemon”, One a “New Powerhouse”].
144. Saif M. Khan, *Maintaining the AI Chip Competitive Advantage of the United States and its Allies*, Center for Security and Emerging Technology, Georgetown University, December 2019, https://cset.georgetown.edu/wp-content/uploads/CSET-Maintaining-the-AI-Chip-Competitive-Advantage-of-the-United-States-and-its-Allies-20191206.pdf.
145. Jane Radecki and Roger C. Schonfeld, “The Impacts of COVID-19 on the Research Enterprise,” *Ithaka S+R*, October 26, 2020, https://doi.org/10.18665/sr.314247.
146. Catherine Aiken, James Dunham, and Remco Zwetsloot, *Career Preferences of AI Talent,* Center for Security and Emerging Technology (CSET), Georgetown University, June 2020, 15.
147. C. Todd Lopez, “Where it Counts, U.S. Leads in Artificial Intelligence,” *Defense News*, July 9, 2020, https://www.defense.gov/Explore/News/Article/Article/2269200/where-it-counts-us-leads-in-artificial-intelligence/.
148. Ministry of Information and Industry Technology, 新一代人工智能产业创新重点任务揭榜工作方案 [New Generation AI Innovation Key Task List and Work Plan], People’s Republic of China, MIIT Announcement, no. 80, November 14, 2018, 17-24, http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c6489400/content.html.
149. 619家“新基建”重点目标企业名单 [Roster of 619 Enterprises Supporting “New Infrastructure” Key Objectives], 5G Industry Circle, June 21, 2020, http://www.rzweiqi.com/third_1.asp?txtid=36.

ISBN 978-1-932946-08-6

90000>

9 781932 946086