CHAPTER 4

CHINA'S HIGH-TECH DEVELOPMENT

SECTION 1: CHINA'S PURSUIT OF DOMINANCE IN COMPUTING, ROBOTICS, AND BIOTECHNOLOGY

Key Findings

- China has laid out an ambitious whole-of-government plan to achieve dominance in advanced technology. This state-led approach utilizes government financing and regulations, high market access and investment barriers for foreign firms, overseas acquisitions and talent recruitment, and, in some cases, industrial espionage to create globally competitive firms.
- China's close integration of civilian and military technology development raises concerns that technology, expertise, and intellectual property shared by U.S. firms with Chinese commercial partners could be transferred to China's military.
- *Artificial intelligence:* China—led by Baidu—is now on par with the United States in artificial intelligence due in part to robust Chinese government support, establishment of research institutes in the United States, recruitment of U.S.-based talent, investment in U.S. artificial intelligence-related startups and firms, and commercial and academic partnerships.
- *Quantum information science:* China has closed the technological gap with the United States in quantum information science—a sector the United States has long dominated—due to a concerted strategy by the Chinese government and inconsistent and unstable levels of R&D funding and limited government coordination by the United States.
- *High performance computing:* Through multilevel government support, China now has the world's two fastest supercomputers and is on track to surpass the United States in the next generation of supercomputers—exascale computers—with an expected rollout by 2020 compared to the accelerated U.S. timeline of 2021.
- *Biotechnology:* The United States' robust biotechnology ecosystem continues to drive U.S. leadership in this sector, but China's state-directed policies have subsidized the establishment of the world's largest genomic sequencing firms and supported China's rapid rise in genomics and biotechnology-related publications.

- *Robotics:* China is developing its industrial and military robotics sector through subsidization of domestic robotics firms, acquisition of foreign knowledge and technology, and recruitment of overseas expertise. This is strengthening the quality and competitiveness of China's manufacturing and its military capabilities.
- *Nanotechnology:* While consistent federal government funding to the National Nanotechnology Initiative has kept the United States at the forefront of nanotechnology, China has become the fastest-growing country for nanotechnology publications and industrialization due to massive government funding, recruitment of overseas talent, and creation of nanotechnology science parks.
- *Cloud computing:* China has largely closed off its cloud computing market to U.S. cloud computing firms—the global leaders—with unfair market access restrictions and onerous regulations. In addition, Chinese cloud computing firms' close ties to the Chinese government raise security concerns over the protection of U.S. customers' sensitive data, including intellectual property and personal information.

Recommendations

The Commission recommends:

- Congress direct the National Science and Technology Council, in coordination with the National Economic Council and relevant agencies, to identify gaps in U.S. technological development vis-à-vis China, including funding, science, technology, engineering, and mathematics workforce development, interagency coordination, and utilization of existing innovation and manufacturing institutes, and, following this assessment, to develop and update biennially a comprehensive strategic plan to enhance U.S. competitiveness in advanced science and technology.
- Congress direct the Federal Bureau of Investigation in concert with the U.S. Department of Commerce's International Trade Administration to expand outreach to and develop educational materials and tools for U.S. academics, businesses, venture capitalists, and startups in dual-use sectors on potential risks associated with Chinese investors and partners, the Chinese government's role in acquiring technology through programs such as the Thousand Talents Program and Project 111, and steps to prevent industrial and cyber espionage.

Introduction

Industries like computing, robotics, and biotechnology are pillars of U.S. economic competitiveness, sustaining and creating millions of high-paying jobs and high-value-added exports.[1] Leadership in these industries has also yielded significant military technological advantages in areas such as weapons design and maintenance, surveillance, communication, and stealth.[2] The United States remains a global technological trailblazer on the strength of its world-renowned education system, innovation ecosystem, funding for basic research and development (R&D), and ability to recruit the world's brightest minds. But the Chinese government has laid out a comprehensive, whole-of-government plan to close the gap and achieve dominance in these areas. This approach sets targets and utilizes government financing and regulations, overseas acquisitions and talent recruitment, high market access barriers, and, in some cases, industrial espionage to create globally competitive firms.[3] The loss of global leadership in these future drivers of global growth, innovation, and warfare would be detrimental to U.S. long-term economic and military competitiveness.

This section builds upon the Commission's 2016 analysis of the impact of China's industrial policies on U.S. commercial aviation, automobile, and semiconductor industries * and examines next-generation, dual-use technologies—critical for advanced manufacturing, Internet of Things,† healthcare, and defense. It lays out China's industrial policies to support its computing, industrial robotics, artificial intelligence (AI), nanotechnology, and biotechnology sectors, compares U.S. and Chinese technological leadership in these sectors, and analyzes the implications of these developments for U.S. innovation, economic prosperity, and military superiority. This section draws from the Commission's March 2017 hearing on China's pursuit of next-generation, dual-use technologies; contracted research; consultations with government officials, academics, and industry experts; and open source research and analysis.

China's Industrial Policies

The Chinese government has laid out industrial plans where the government—not market forces—plays a central role in developing Chinese firms into the global leaders in cutting-edge, dual-use technologies (see Figure 1).‡ These industrial plans establish the government's strategy for sector development at the national and local government levels and set targets for localization, market creation, and productivity.[4] To meet these objectives and cultivate local and national market leaders (the so-called "national champions"§), central and local governments implement comprehensive industrial policies such as strong state funding, a protected domestic market, selective recruitment of foreign investment, imports, and talent, and, in some cases, industrial espionage (see Table 1). By comparison, the U.S. government pursues a market-based development strategy, where government support is primarily concentrated at the early stages of development. The U.S. government finances critical foundational research and connects industry, government, and academia through public-private partnerships to accelerate the transition of research findings into commercial products or services.[5]

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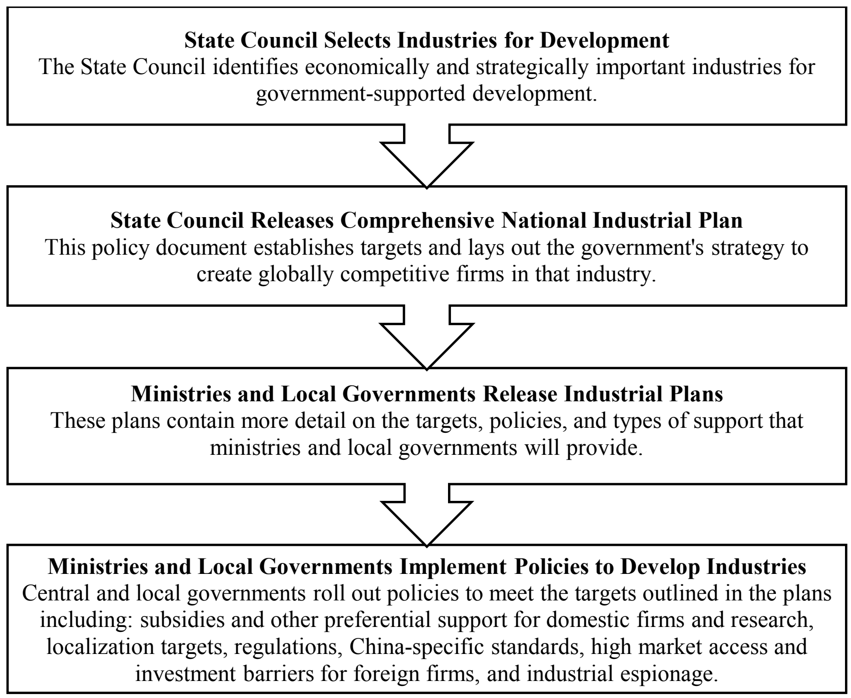
* For analysis on the impact of China's industrial policies on U.S. commercial aviation, automobile, and semiconductor industries, see U.S.-China Economic and Security Review Commission, Chapter 1, Section 3, "China's 13th Five-Year Plan," in *2016 Annual Report to Congress*, November 2016, 151–161.

† The Internet of Things is the interconnectivity between physical objects such as a smartphone or electronic appliance via the Internet that allows these objects to collect and share data. Harald Bauer, Mark Patel, and Jan Veira, "The Internet of Things: Sizing up the Opportunity," *McKinsey & Company*, December 2014.

‡ For a comprehensive analysis of China's state-directed plans and their impact on 11 industries, see Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016.

§ National champions are domestic firms leading in their industry—based on market share, volume of sales, and size—that enjoy strong political and financial support from the Chinese government.

Figure 1: How the Chinese Government Rolls out Its Industrial Policies



Source: Compiled by Commission staff.

China's state-led approach catapulted China to global dominance in strategic industries such as solar, wind,* aluminum, and steel in less than a decade.[6] But this strategy came at the cost of distorted global and domestic market conditions, inefficient allocation of resources, rampant overproduction and overcapacity, and weak innovation incentives.[7] For example, in the solar sector (a strategic emerging industry), China's Ministry of Finance subsidized 50 to 60 percent of production costs of select domestic solar companies and 50 to 70 percent of installation costs for solar generation and distribution systems.[8] State-owned banks also allocated around $41 billion from January 2010 to September 2011 to rapidly expand solar panel manufacturing capacity.[9] By 2016, China had overtaken the United States and Germany—the early global leaders—producing 71 percent of the world's solar modules and accounting for a majority of global solar manufacturing capacity at all stages of production.† But this massive increase in production and capacity quickly

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* For in-depth analysis of China's wind and solar policies, see Iacob Koch-Weser and Ethan Meick, "China's Wind and Solar Sectors: Trends in Deployment, Manufacturing, and Energy Policy," *U.S.-China Economic and Security Review Commission*, March 9, 2015.

† Solar manufacturing is composed of four major production steps: polysilicon, wafer, cell, and module. Based on 2016 data from IHS Markit, China accounted for 52 percent of polysilicon manufacturing capacity, 81 percent of silicon-solar-wafer manufacturing capacity, 59 percent of silicon-solar-cell manufacturing capacity, and 70 percent of crystalline solar-module manufacturing capacity. Donald Chung, Kelsey Horowitz, and Parthiv Kurup, "On the Path to SunShot: Emerging Opportunities and Challenges in U.S. Solar Manufacturing," *National Renewable Energy Laboratory*, May 2016, 5; Jeffrey Ball et al., "The New Solar System: China's Evolving Solar

exceeded domestic demand. As a result, Chinese firms started to dump their subsidized products on the global market, contributing to an 80 percent decline in international prices from 2008 to 2013 and leading to 86 bankruptcies and closures (largely at U.S. and EU competitors) from 2009 to 2015.[10]

In addition, Chinese researchers, incentivized by cash bonuses as high as $165,000 per paper accepted by international top-tier publications, rapidly increased their number of academic publications, making China the world's second largest source of global publications.* However, this increase in quantity has not been matched by quality. For example, in April 2017, a cancer research journal, *Tumor Biology*, retracted 107 papers by Chinese researchers between 2012 and 2016 due to fabricated peer reviews. China's Ministry of Science and Technology, Ministry of Education, and the China Association for Science and Technology jointly conducted an investigation into these allegations and, in July 2017, announced disciplinary action for more than 400 authors listed on the retracted reports.[11]

Robert D. Atkinson, president of the Information Technology and Innovation Foundation, warned that Chinese policymakers use industrial policies "to autarkically† supply Chinese markets for advanced technology products with their own production while still benefitting from unfettered access to global markets for their technology exports and foreign direct investment."[12] In August 2017, the Office of the U.S. Trade Representative announced it would start investigations to determine "whether acts, policies, and practices of the Government of China related to technology transfer, intellectual property, and innovation are unreasonable or discriminatory and burden or restrict U.S. commerce."[13]

Table 1: China's Industrial Policy Toolbox

Policy Tool	**Description**
Localization Targets	Within its industrial plans, the Chinese government sets targets for domestic and international market share that should be held by local technology and production. For example, the Made in China 2025 Key Area Technology Roadmap set a target to increase the state-owned aerospace manufacturer Commercial Aircraft Corporation of China's share of the domestic wide-bodied aircraft market (a strategic industry since 2006) from 5 percent in 2020 to 10 percent in 2025.[14]

Industry and Its Implications for Competitive Solar Power in the United States and the World," *Stanford University, Steyer-Taylor Center for Energy Policy and Finance*, March 2017, 18.

*For publications in the prestigious *Science* and *Nature* journals, the lead Chinese author, on average, received a cash bonus of $43,783 in 2016. By comparison, Saudi Arabia's Prince Sultan University, home of the second highest cash bonus for publications, reached a high of $19,999 per paper; Qatar University, the third highest, totaled $13,733. Alison Abritis and Alison McCook, "Cash Bonuses for Peer-Reviewed Papers Go Global," *Science*, August 10, 2017; Wei Quan, Bikun Chen, and Fei Shu, "Publish or Impoverish: An Investigation of the Monetary Reward System of Science in China (1999–2016)"; Yuan Yang and Archie Zhang, "China Launches Crackdown on Academic Fraud," *Financial Times*, June 18, 2017.

†Autarky is an economic system and an ideology based on implementing policies in a manner that supports national economic self-sufficiency and independence.

Table 1: China's Industrial Policy Toolbox—*Continued*

Policy Tool	Description
State Funding for Industry Development	The central government lays out national investment funds, subsidies, tax breaks, preferential loans, export subsidies and guarantees, and other forms of financial support to develop national champions in strategic sectors. For example, in the solar sector (a strategic emerging industry), China's Ministry of Finance subsidized 50 to 60 percent of production costs of select solar companies and 50 to 70 percent of installation costs for solar generation and distribution systems.[15] Local governments, which account for the largest share of financial aid, provide additional support to local champions. [16] At least 21 cities and 5 provinces have pledged a combined $6 billion (renminbi [RMB] 40 billion)* in subsidies for robotics (a Made in China 2025 strategic industry). These subsidies account for an estimated 10 percent of total operation revenue for Chinese robotics firms Siasun and Estun. Local governments are also subsidizing between 15 and 30 percent of the purchase price of robotics to encourage greater usage.[17] Designated national champions also receive advantageous capital terms from state-owned banks and investment funds (e.g., wind turbine manufacturer Goldwind received a $5.5 billion loan from the China Development Bank).[18]
Government R&D Funding	The Chinese government provides significant R&D funding to strategic sectors. From 2005 to 2015, total government R&D spending grew more than 350 percent to reach $44.5 billion (RMB 301.3 billion).[19] China's R&D expenditures are rapidly catching up to the United States with China's total R&D spending (public and private) increasing from 26.5 percent of total U.S. R&D expenditures in 2005 to 75.1 percent in 2015.[20]
Government Procurement	The Chinese government leverages its large central and local government procurement markets to benefit domestic firms in strategic sectors. For example, in 2012, the central government mandated its agencies to purchase only Chinese auto brands, leading several municipal and provincial governments to follow suit.[21]
Technology Standards	The Chinese government has repeatedly created China-specific standards to raise the costs of market entry for foreign firms. For example, the People's Bank of China announced a new technical encryption standard for bank cards—incompatible with existing international standards and only used by the state-owned China UnionPay—effectively forcing foreign electronic payment firms such as Visa and MasterCard to spend additional money to redesign their cards to meet the standard.†
Regulations	The Chinese government advantages domestic firms by setting high regulatory thresholds for market entry and creating vague regulations that allow for discretionary enforcement and interpretation. In the automobile sector, for instance, the government requires foreign firms to form joint ventures with state-owned firms as the price of market entry.[22]

*Unless noted otherwise, this section uses the following exchange rate throughout: $1 = RMB 6.77.

†For more information on China's payments market and market access challenges, see Chapter 1, Section 3, "U.S. Access to China's Consumer Market."

Table 1: China's Industrial Policy Toolbox—*Continued*

Policy Tool	Description
Foreign Investment Restrictions and Import Guidance	Through its Catalogue on Guiding Foreign Investment and Catalogue on Encouraged Imported Technology and Products, the Chinese government directs foreign investment and technology imports toward strategic sectors by designating industries as either "encouraged," "permitted," or "restricted" to foreign investment.* Foreign investment in targeted sectors is first welcomed to build domestic capacity, but after domestic firms become competitive, the government gradually restricts this investment to provide a protected market for domestic firms. For example, the automobile industry—a strategic emerging industry under the 12th Five-Year Plan—shifted from "encouraged" in 1994–2010 to "permitted" in 2011–2014 to "restricted" in 2015.[23]
Foreign Talent	The Chinese government is recruiting overseas Chinese and foreign experts and entrepreneurs in strategic sectors to teach and work in China, most notably through its Thousand Talents Program and Project 111. The Thousand Talents Program was launched in December 2008 and has brought more than 4,000 foreigners to China's scientific laboratories, companies, and research centers. The Chinese government also uses research and startup funding to incentivize foreign experts and entrepreneurs to split time between their positions overseas and in China.[24] Project 111 was launched in 2006 to recruit 1,000 foreign experts in strategic sectors from the world's top 100 universities and research institutes.[25]
Industrial Espionage	The Chinese government continues to conduct pervasive industrial espionage† against U.S. companies, universities, and the government and direct efforts to circumvent U.S. export controls to gain access to cutting-edge technologies and intellectual property in strategic sectors.[26]

Source: Compiled by Commission staff.

Made in China 2025 and Internet Plus Initiatives

The "Made in China 2025" and "Internet Plus" initiatives—two influential national industrial plans emphasized in China's 13th Five-Year Plan‡—seek to capitalize on the rise of integrated digital technology and automation to help transition China's economy to higher-value-added manufacturing and services and spur the creation of national champions in emerging industries.[27] Made in China 2025 targets ten key sectors for additional government support: (1) new energy vehicles, (2) next-generation information technology (IT), (3) biotechnology, (4) new materials, (5) aerospace, (6) ocean engineering and high-tech ships, (7) railway, (8) robotics, (9) power equipment, and (10) agricultural machinery.[28] Most of these sectors

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*Prohibited sectors are those where the Chinese government is seeking to maintain a state monopoly (such as postal companies), protect Chinese firms from competition, or restrict foreign access to national-security-related industries (such as weapons manufacturing). Wayne M. Morrison, "China-U.S. Trade Issues," *Congressional Research Service*, December 15, 2015, 25.

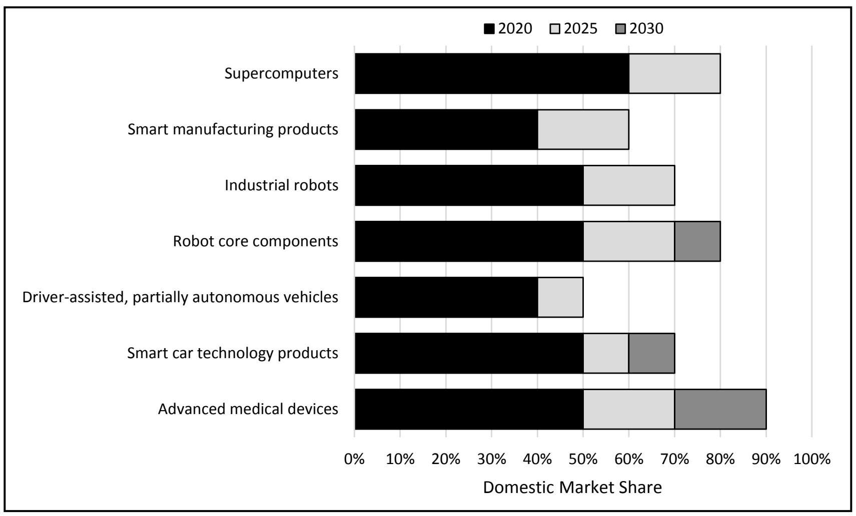
†For more information on China's cyber espionage campaigns and their influence on Chinese acquisitions of U.S. firms, see Chapter 1, Section 2, "Chinese Investment in the United States" of this Report. For more information on cyber-enabled commercial espionage, see U.S.-China Economic and Security Review Commission, Chapter 1, Section 4, "Commercial Espionage and Barriers to Digital Trade," in *2015 Annual Report to Congress*, November 2015, 192–219.

‡For more information on China's 13th Five-Year Plan and its targets, see Katherine Koleski, "The 13th Five-Year Plan," *U.S.-China Economic and Security Review Commission*, February 14, 2017.

are long-held strategic industries. For example, next-generation IT was previously supported as a strategic emerging industry in 2010 and a heavyweight industry in 2006; biotechnology was previously supported as a strategic emerging industry in 2010.[29] Internet Plus aims to capitalize on China's huge online consumer market by building up the country's domestic mobile Internet, cloud computing, massive amounts of data (big data), and the Internet of Things sectors.[30]

These state-directed initiatives seek to build domestic firms that are globally competitive with a goal of gradually substituting foreign technology and products with local technology and production first at home, and then abroad.[31] The Chinese Academy of Engineering, an influential State Council think tank, released the Made in China 2025 Key Area Technology Roadmap in October 2015 outlining localization targets for strategic sectors (see Figure 2).[32] Reaching these localization targets would gradually close China's growing market to U.S. and other foreign firms, a major loss of market and job opportunities.[33]

Figure 2: Select Made in China 2025 Key Area Technology Roadmap's 2020, 2025, and 2030 Localization Targets



Source: Chinese Academy of Engineering, Expert Commission for the Construction of a Manufacturing Superpower, *Made in China 2025 Key Area Technology Roadmap*, October 29, 2015, 14, 22, 40, 114, 182. Translation.

According to the U.S. Chamber of Commerce, Made in China 2025 "aims to leverage the power of the state to alter competitive dynamics in global markets in industries core to economic competitiveness."[34] For example, since 2014, the central government has announced at least $250.7 billion (RMB 1.7 trillion) in state funding to support these strategic sectors' development and acquisition of foreign technology and expertise (see Table 2). Addendum I provides an overview of China's industrial policies in five strategic sectors.

Table 2: Select Government Funds to Support Strategic Sectors since 2014

Fund	Date Announced	Amount (billions)
National Integrated Circuit Fund	June 2014	$107.5 (RMB 720)
Emerging Industries Investment Fund	January 2015	$6 (RMB 40)
Advanced Manufacturing Fund	June 2016	$3 (RMB 20)
Venture capital fund for state-owned enterprise innovative technology and industrial upgrading fund	August 2016	$30 (RMB 200)
China Development Bank support for Made in China 2025	November 2016	$44.8 (RMB 300)
China Internet Investment Fund	January 2017	$14.9 (RMB 100)
Credit lines for China Internet Investment Fund participants	January 2017	$22.4 (RMB 150)
State-owned enterprise fund for strategic sectors	May 2017	$22.4 (RMB 150)
TOTAL		**$250.7 (RMB 1,680)**

Source: Various.[35]

Computing

Computing utilizes computer hardware and software technology to complete a task and is the foundation for the rise of the Internet of Things, data analytics, AI, advanced manufacturing, and autonomous systems. The Chinese government seeks to break its dependence on imports and develop domestic champions in high-performance computing (HPC), cloud computing, and quantum information science.

High-Performance Computing

Definition. HPC utilizes large networks of computers (commonly known as supercomputers) to execute software programs that process big data to solve complex problems.[36] Access to the most advanced computing capabilities has become indispensable for researchers, companies, and governments to make breakthroughs in technological and scientific innovation and research.[37] Use of the most advanced HPC provides a competitive advantage in all commercial data analytics, modeling, and simulations as well as defense-related tasks such as communications, cryptography, signals processing, weapons design and testing (especially nuclear weapons),* and war gaming.[38]

Industrial Policy. The Chinese government has directed at least $1.1 billion (RMB 7.6 billion) to HPC since 2009 and established targets for domestic firms to account for 60 percent of its HPC market share by 2020.[39] The Chinese government budgeted $270 million

*The U.S. Department of Energy uses supercomputers to conduct simulations of nuclear explosions and virtually test the effectiveness and reliability of its nuclear weapons stockpile, allowing the U.S. government to move away from physical nuclear weapons tests. Stephen J. Ezell and Robert D. Atkinson, "The Vital Importance of High-Performance Computing to U.S. Competitiveness," *Information Technology and Innovation Foundation*, April 2016, 11.

(RMB 1.8 billion) to build Sunway TaihuLight, the world's fastest supercomputer; by comparison, the U.S. government allocated $325 million to construct two new supercomputers that are expected to surpass Sunway TaihuLight with one completed in 2017 and one in 2018.[40] Overall, these efforts have successfully transformed China into a global HPC leader based on overall speed, processing capacity, and rollout of indigenous design.[41]

Chinese achievements in HPC include:

- *Building the world's two fastest supercomputers:* The Sunway TaihuLight's 93 petaflop processing speed is roughly equal to the combined processing capacity of the next five fastest supercomputers on the Top 500 list (a list of the world's most powerful computer systems),* and is 5.3 times faster than that of the highest-ranked U.S. supercomputer, the Titan.[42] It is the world's first supercomputer composed entirely of Chinese-designed and Chinese-made processors.[43] Tianhe-2 is the world's second-fastest computer and is roughly twice as fast the Titan.[44] Chinese high-performance and cloud computing firm Inspur built the Tianhe system using Intel processors.[45]
- *Becoming the country with the second-largest number of supercomputers:* As of June 2017, the United States had 168 supercomputers followed by China at 160, together accounting for around two-thirds of the Top 500 list. China's Sunway TaihuLight and Tianhe-2 are the two highest ranked, with the U.S. Titan at number four. Japan, with 33, has the third-highest number of supercomputers.[46]
- *Receiving an international award for application of HPC:* China has lagged behind the United States in software application development for these supercomputers, but the gap is closing. In November 2016, Chinese researchers, relying on the Sunway TaihuLight to run their data analytics problem, for the first time won the distinguished Gordon Bell Prize, which is a benchmark for the application of HPC to complex science, engineering, and large-scale data analytics problems.[47] In total, Chinese researchers relying on Chinese supercomputers accounted for three out of the six finalists in 2016.[48]

In 2011, foreign hardware suppliers IBM and Hewlett Packard held 35 percent and 13 percent, respectively, of the Top 100 systems in China.† By 2016, IBM had sold its HPC business to the Chinese computer manufacturing firm Lenovo, and Hewlett Packard's share had fallen to 2 percent.[49] During the same period, Lenovo's share

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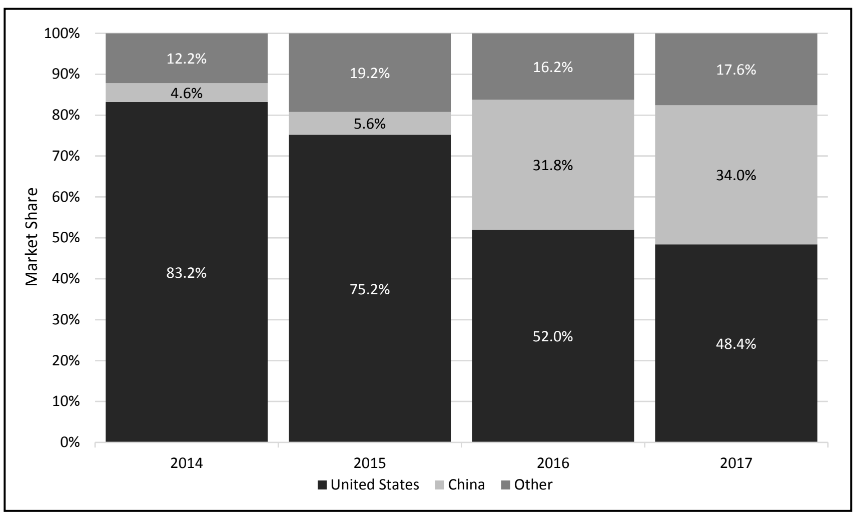
*The Top 500 list is a biannual ranking of the 500 fastest commercially available supercomputer systems based on its maximum benchmark performance solving a dense matrix of linear equations. Participation in the list is voluntary, but most vendors and governments are incentivized to participate to demonstrate their supercomputers' global competitiveness. The quick rise in the number of Chinese supercomputers on the Top 500 list is in part related to their increased participation on the list. Top 500, "About." *https://www.top500.org/project/*; U.S.-China Economic and Security Review Commission, *Hearing on China's Pursuit of Next Frontier Tech: Computing, Robotics, and Biotechnology*, written testimony of Addison Snell, March 16, 2017, 6.

†The Top 100 list is compiled by the Specialty Association of Mathematical and Scientific Software of the China Software Industry Association, the Evaluation Center of High Performance Computer of the National 863 Plan, and the High Performance Computing Technique Committee of the China Computer Federation. It lists China's leading 100 supercomputers based on performance. Zhang Yunquan et al., *2011 China TOP100 List of High Performance Computer*, November 2011. *https://www.top500.org/files/SAMSS-2011-China-HPC-TOP100-201103--en.pdf.*

of the domestic HPC market increased from 1 percent to 34 percent in 2016.[50] Inspur grew its HPC market share from 7 percent to 19 percent from 2011 to 2016; Chinese HPC firm Sugon (formerly Dawning) maintained a 34 percent market share.[51] In his written testimony at the Commission's March 2017 hearing, Addison Snell, chief executive officer at the high-performance industry consulting firm Intersect360 Research, noted that while there is significant growth potential in China, U.S. firms "have little access to government bids," which account for the largest share of market demand.[52]

As of June 2017, Chinese firms accounted for 34 percent of the Top 500 market share, while U.S. firms such as Hewlett Packard and Cray made up 48.4 percent (see Figure 3).[53] This is a dramatic reduction from just three years ago, when U.S. firms accounted for 83.2 percent and Lenovo, the largest Chinese firm in the top ten vendors, made up 3.8 percent.[54]

Figure 3: U.S. and Chinese HPC Vendors' Market Share of the Top 500 Supercomputers, 2014–2017



Note: Data reflect the market share of the U.S. and Chinese HPC vendors listed in the top ten largest vendors for June of each year. These U.S. and Chinese firms alone account for at least 80 percent of the total Top 500 supercomputer market.

Source: Top 500, "List Statistics," June 2014; Top 500, "List Statistics," June 2015; Top 500, "List Statistics," June 2016; Top 500, "List Statistics," June 2017.

Comparison of U.S. and Chinese Capabilities. The United States still maintains a lead in HPC production, usage, and software application development, but China has the world's two fastest supercomputers, maintains the world's second-largest number of supercomputers, and is on track to beat the United States in rolling out the next generation of HPC.[55] The U.S., Chinese, Japanese, and the EU governments are developing the next generation of supercomputers—exascale computers—capable of applying quintillion calculations per second to complex problems.[56] Meng Xiangfei, director of applications at the National Supercomputing Center in Tianjin, announced that if China achieves the necessary breakthroughs in high-performance processors, he expects China to complete a prototype by 2018 and have a fully operating exascale computer by 2020.[57] To keep pace with China and Japan, the U.S. Department of Energy, which spearheads U.S. government HPC and exascale development efforts,* accelerated its initial 2023 timeframe to 2021, though this is contingent on federal funding.[58] Mr. Snell noted in his testimony that the United States "is falling behind in the leading edge of advancement, and simultaneously losing the ability to rein in other countries via export control" due in part to the level and consistency of Chinese government funding for indigenous HPC (see textbox "U.S. Export Controls on HPC Components to China").[59]

U.S. Export Controls on HPC Components to China

The U.S. government has raised concerns regarding the pace of China's development of HPC and the lack of separation between China's civilian and defense uses of supercomputing.[60] On February 18, 2015, the U.S. Department of Commerce added export license requirements for HPC components headed to the National University of Defense Technology and the National Supercomputing Centers located in Changsha, Guangzhou, and Tianjin because the National University of Defense Technology used U.S.-produced components in Tianhe-1A and Tianhe-2 to simulate nuclear explosive activities, which the U.S. government deemed "contrary to the national security and foreign policy interests of the United States."[61] This ban has prevented China from upgrading its Tianhe-2 system and will present challenges for at least 154 other Chinese supercomputers that rely on Intel components.[62]

Cloud Computing

Definition. Cloud computing refers to the storage, management, and processing of data and software services on remote servers rather than a local or personal computer.[63] This capability is the foundation for big data storage and allows users to access and use technology resources on demand and at any place in the world. Providers locate infrastructure where it optimizes resource use and scale capabilities up or down to meet customer demand, unlocking innovation by firms such as Uber and Netflix that can increase their IT resource use with growing demand for their services.[64]

Industrial Policy. China's cloud computing market is nascent but growing quickly.† In his testimony to the Commission, Mark Brinda, partner at the consulting firm Bain and Company, projected

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* In June 2017, the U.S. Department of Energy announced $430 million in exascale R&D with $258 million (60 percent) in federal funding over three years and $172 million (40 percent) from private firms. U.S. Department of Energy, *Department of Energy Awards Six Research Contracts Totaling $258 Million to Accelerate U.S. Supercomputing Technology*, June 15, 2017.

† For more information on China's state-led development of cloud computing, see Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016, 184–192; Leigh Ann Ragland et al., "Red Cloud Rising: Cloud Computing in China," *Defense Group, Inc.* (prepared for the U.S.-China Economic and Security Review Commission), September 5, 2013.

that China's cloud computing market would grow from $1.5 billion in 2013 to $13–19 billion by 2020.[65] By comparison, the U.S. market is expected to increase from around $65 billion in 2013 to $220 billion by 2020.[66] Chinese government initiatives for developing its own cloud computing industry include: at least $7.7 billion (RMB 52 billion) in financial support under the 12th Five-Year Plan; a $177.3 billion (RMB 1.2 trillion) investment to construct more than 56,250 miles (90,000 kilometers) of high-speed fiber optic cables and two million 4G base stations* under the 13th Five-Year Plan; and expanding usage through government procurement.[67]

Chinese government laws and regulations require state-owned enterprises—responsible for two-thirds of China's IT spending—to purchase services from Alibaba's subsidiary, Aliyun, and other domestic cloud computing firms.[68] According to China's Government Procurement Law:

> *The government shall procure domestic goods, construction and services, except in one of the following situations: (1) where the goods, construction or services needed are not available within the territory of the People's Republic of China or, though available, cannot be acquired on reasonable commercial terms; (2) where the items to be procured are for use abroad; and (3) where otherwise provided for by other laws and administrative regulations.*[69]

Through a combination of these protections and Alibaba's comprehensive business service offerings that attract Chinese startups, Aliyun built capacity and gained more than 50 percent of the Chinese market.[70]

Comparison of U.S. and China Capabilities. Globally, U.S. firms such as Amazon Web Services, Google, Microsoft, Salesforce, VMware, and IBM accounted for at least four of the top five firms in each cloud computing market in 2016.[71] Mr. Brinda attributes this leadership to a large, highly skilled developer ecosystem, the close nexus of developers, venture capitalists, and acquirers, and a large domestic market.[72] But while the rapid expansion of China's cloud computing market presents enormous opportunities, foreign cloud computing firms face significant regulatory barriers to entering and operating in China's market, including:[73]

- *Prohibited sectors:* Foreign firms are banned from providing cloud services to particular industries, such as banking.[74] In addition, foreign firms seeking to provide cloud services to the Chinese government must disclose key operating data and may be required to provide their source code to the government.[75] In an effort to address these concerns while preventing alteration or revealing their proprietary software, in September 2016, Microsoft announced the opening of the Microsoft Transparency

* 4G base stations can handle more network traffic at a faster pace. China is also aggressively pursuing the next generation 5G technology that would be critical to setting international standards and enabling autonomous vehicles use. Ma Si, "Big Three Locked in Race for High-Speed Market," *China Daily*, July 20, 2017. For more information on China's pursuit of 5G technology, see Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016, 177–184.

Center in Beijing to provide a facility—similar to ones in the United States and EU—where government IT experts can test and analyze Microsoft's products.[76]

- *Data localization regulations:* The Chinese government mandates firms keep "important data" within China.[77] "Important data" comprise data related to national security, economic development, and social or public interest encompassing sectors ranging from e-commerce to utilities.[78] This vague term compels U.S. and other foreign cloud computing providers to create data storage centers in China as a joint venture and hire local workers to manage these centers, raising costs and increasing data privacy concerns.[79]
- *Joint venture requirements:* Foreign firms must form joint ventures with local firms to manage their data storage centers.[80] In 2012, Microsoft formed a partnership with the Chinese firm 21Vianet, where 21Vianet supplies the cloud computing infrastructure and Microsoft provides its Azure cloud platform and services. 21Vianet also supplies the infrastructure for Amazon and IBM in China.[81] In March 2017, IBM and Wanda Internet Technology Group formed a similarly structured joint venture.[82] In July 2017, Apple announced that it would open a data center with the provincial state-owned Chinese data management firm Guizhou-Cloud Big Data Industry.[83] In contrast, Chinese cloud computing firms such as Tencent and Aliyun are able to open and operate their data centers freely in the United States.[84]
- *Cross-border data transfer restrictions:* China's Cybersecurity Law imposes overly broad restrictions on data flowing outside of China, effectively enabling the government to prohibit any data transfers they deem necessary.[85] These restrictions are contrary to the global shift toward data centralization, which is critical for data analytics, technology optimization, and integrated global service and R&D.[86] (For more information on China's Cybersecurity Law, see Chapter 1, Section 1, "Year in Review: Economics and Trade.")

China's restrictive market access provisions remain in place despite China's commitment under the World Trade Organization (WTO) to open its cloud computing market to foreign firms.[87] In addition, according to a March 2017 report by the U.S. Chamber of Commerce, "Chinese efforts to exert greater control over where commercial data is stored and how it is transferred are skewing the decision-making process for companies that must decide where products are made and innovation takes place."[88] The United States has repeatedly raised concerns over China's violations of its WTO commitments and data storage and cross-border transfer restrictions with the Chinese government, but achieved limited progress.[89]

Quantum Information Science

Definition. Quantum information science uses atomic and subatomic level mechanics to acquire, process, and transmit information at a level that will surpass existing technology. Whereas existing electronic communication and computation is a binary system in which a series of 0s and 1s encode instructions and data by turning transistors on or off, quantum bits can exist as 0, 1, or both simultaneously. This multistate allows a quantum computer to run multiple problems at the same time rather than one by one, theoretically performing a task in a fraction of the time of existing supercomputers.[90] In addition, quantum mechanics allow for two or more particles to be connected (or "entangled") such that changing the quantum properties of one particle automatically changes the other no matter the distance between the particles. These unique properties enable "quantum teleportation," whereby a sender transmits information by making a series of changes to entangled particles (usually light photons) on one end that will result in the receiver observing the same changes to particles on the other end without any physical transmission taking place. The receiver can then decrypt the message using an agreed-upon code, the quantum decryption key.[91]

Quantum information science is still in its infancy, but it is expected to rewrite the foundations of IT.[92] For instance, quantum computing will likely revolutionize financial modeling and chemical, biological, and material science R&D, creating a competitive advantage for researchers and businesses.[93] Militarily, quantum-based technologies would provide several strategic benefits that could negate existing U.S. advantages in intelligence collection and stealth and weaken U.S. encrypted communication security.[94] Quantum cryptography would ensure virtually unbreakable communication networks, and quantum computing could decrypt sensitive communications transmitted via existing satellite and fiber networks, offering asymmetrical communication security and decryption advantages over an adversary.[95]

Industrial Policy. The Chinese government is aggressively developing this industry to leapfrog U.S. preeminence in existing IT sectors and achieve global market dominance, according to testimony from John Costello, senior analyst at the business risk intelligence firm Flashpoint.[96] Tim Byrnes, a quantum physicist at New York University, noted in July 2017 that "it's amazing how quickly China has gotten on with quantum research projects that would be seen as too expensive to do elsewhere."[97] With the government's help, Chinese researchers have made significant progress, most notably in operationalizing and commercializing quantum cryptography and communication. Major new developments include:

- *Launching the world's first quantum science satellite:* In August 2016, the Chinese government launched the world's first quantum science satellite, which the U.S. Department of Defense characterized as a "notable advance."[98] Access to this satellite has allowed Chinese researchers to conduct pioneering quantum experiments.
- *Demonstrating satellite-to-ground and ground-to-satellite quantum teleportation:* In June 2017, Chinese scientists published their results on using the quantum satellite launched in August 2016 to teleport entangled light photons' properties back to corresponding photons on Earth over a distance of up to 750 miles (1,200 kilometers), shattering the previous world record of 89 miles (143 kilometers) set in 2012 by Austrian researchers.[99]

In an August 2017 publication, Chinese researchers announced the world's first experiment teleporting entangled light photons' properties from Earth to satellite-based corresponding photons at a distance of up to 875 miles (1,400 kilometers). These groundbreaking studies establish the foundation for a global quantum Internet* and a quantum communication network.[100]

- *Transmitting satellite-to-ground quantum decryption keys:* In August 2017, Chinese researchers published their findings on using the same satellite to transmit a quantum decryption key to two separate ground stations in China, allowing both stations to securely encrypt and decrypt data transmitted to each other via traditional communication channels. This method achieved up to 20 orders of magnitude the efficiency of data sent over similar length optical networks.[101] In September 2017, the Chinese Academy of Sciences used this satellite to transmit a quantum decryption key to its partners at the Austrian Academy of Sciences. The Austrian and Chinese researchers then used this key to encrypt their standard virtual private network (VPN) protocol video data and hold a secure 30-minute video conference between Vienna and Beijing. This experiment represents a key breakthrough in quantum key decryption—a building block for quantum communication.[102]

- *Constructing quantum optical fiber communication networks:* In September 2017, the Chinese government operationalized the world's largest quantum-linked optical fiber communications system between Beijing and Shanghai to securely transmit government, finance, and other sensitive information.[103] Due to the limits of existing technology, this 1,250 mile (2,000 kilometer) system is composed of quantum optical fibers linked by 32 conventional telecommunications repeaters that refresh the transmissions approximately every 62.5 miles (100 kilometers).[104] In mid-September 2017, China completed construction of its first citywide commercial quantum communication network in Jinan connecting 242 users at the cost of $17.7 million (RMB 120 million); Wuhan and other major Chinese cities are rolling out similar quantum networks.[105]

Comparison of U.S. and Chinese Capabilities. According to Mr. Costello, the United States "remains at the forefront of quantum information science, but its lead has slipped considerably."[106] The United States still maintains a lead in total quantum-related patent applications, quantum computing publications, and public and private quantum technology R&D spending.[107] But China has now surpassed the United States to become the world leader in quantum communication with Chinese researchers conducting the first public studies on satellite-to-ground and ground-to-satellite quantum teleportation and satellite-to-ground quantum decryption key transmission using the world's first quantum science satellite. China has also surpassed the United States in the number of patent applications

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*A quantum Internet would be a global network of quantum computers. Stefano Pirandola and Samuel L. Braunstein, "Physics: Unite to Build a Quantum Internet," *Nature* 532:7598 (April 12, 2016).

in quantum cryptography and caught up to the United States in the number of patent applications in quantum-key distribution and quantum sensors (see Table 3).[108]

Table 3: U.S. and China Quantum-Related Patent Applications and R&D Spending, 2015

Criterion	United States	China
Total Number of Patent Applications	918	522
Quantum Computing	295	29
Quantum Cryptography	233	367
Quantum Sensors	105	104
Quantum-Key Distribution	151	156
Annual Unclassified Quantum Technology R&D Spending (Share of Global Spending)	$419.1 million (24 percent)	$256.1 million (14.7 percent)

Source: Economist, "Here, There, and Everywhere," March 9, 2017.

According to Mr. Costello, U.S. leadership in quantum information science eroded as "the lack of funding, structural and institutional issues, and lack of government coordination have reduced both the levels and consistency of support that are necessary to maintain capacity" as compared with China's sustained whole-of-government approach.[109] A July 2016 report by the Obama Administration's Interagency Working Group on Quantum Information Science highlighted five key challenges to further U.S. progress in the field: institutional boundaries between and within research laboratories and government departments, insufficient education and workforce training, slow technology and knowledge transfer from universities or national laboratories to the private sector, inadequate availability of materials and fabrication capabilities, and unstable levels of research funding.[110]

Industrial Robotics

Definition. Industrial robotics—manufacturing robots that are programmed with varying degrees of autonomy to weld, transport, assemble, and spray—are improving manufacturing productivity and quality through more precise, consistent, quick, and efficient production. The integration of robotics, computing, big data, AI, and nanotechnology is enhancing advanced commercial and military manufacturing and unmanned aerial, undersea, and land vehicles' capabilities.[111] (For more information on military robotics, see Chapter 4, Section 2, "China's Pursuit of Advanced Weapons.")

Industrial Policy. The Chinese government is encouraging the adoption of industrial robots to improve its manufacturing sector and compensate for its shrinking and increasingly costly workforce.* China became the world's largest market for industrial robotics in 2013 and accounted for 27 percent of industrial robotics

*For more information on China's industrial, service, and military robotics development, see Jonathan Ray et al., "China's Industry and Military Robotics Development," *Defense Group, Inc.* (prepared for the U.S.-China Economic and Security Review Commission), October 25, 2016.

installed globally in 2015, largely driven by demand from China's automotive and electrical industries.[112] But China's robot market maturity remains low, with only 49 robots per 10,000 workers in 2015 compared with the leader, South Korea, at 531 robots per 10,000 workers and the United States, ranked fifth, at 176 robots per 10,000 workers.[113]

Foreign companies, primarily from Japan and Germany, supplied 69 percent of China's installed robotics in 2016, but China is looking to reduce this dependence.[114] The Made in China 2025 initiative set a target to increase Chinese industrial robotics firms' share of the domestic market from 31 percent in 2016 to 70 percent by 2025, with core components—where most of the value is concentrated—to reach 70 percent by 2025.[115] To close its technological gap and reach its import substitution targets, the Chinese government:

- *Offers subsidies:* At least 21 cities and 5 provinces have pledged a combined $6 billion (RMB 40 billion) in subsidies for robotics, prioritizing local Chinese robotics firms. The subsidies account for an estimated 10 percent of total operation revenue for Chinese robotics firms Siasun and Estun. Local governments are also subsidizing between 15 and 30 percent of the purchase price of robotics to encourage greater usage. These subsidies have encouraged a proliferation of new Chinese robotics firms—around 400 of China's 800 robotics firms were set up in 2015.[116] Such rapid expansion risks recreating the overproduction and overcapacity that similar subsidies under the 12th Five-Year Plan (2011–2015) created for solar and wind industries.[117] Vice Minister of Industry and Information Technology Xin Guobin raised these concerns in June 2016, stating that China's robotics firms are "plagued by low quality, overinvestment and too much duplication."[118]

- *Facilitates acquisitions:* In the last few years, state investment funds and policies are directly and indirectly supporting the surge in Chinese acquisitions of foreign robotics firms. These acquisitions seek to gain access to foreign technology, intellectual property, and expertise.[119] Notable deals include Wanfeng's April 2016 purchase of the U.S. automotive manufacturing and assembly robotics firm Paslin, Midea's August 2016 acquisition of the German industrial robotics leader Kuka, and state-owned Shanghai Electric's October 2016 acquisition of the German aerospace robotics firm Broetje Automation.[120]

- *Promotes overseas recruitment:* The Chinese government is recruiting overseas Chinese and foreign experts and entrepreneurs to come teach and work in China on advanced robotics through its Thousand Talents Program and Project 111.[121] These programs successfully attracted former nanorobotics professor at Michigan State University Lianqing Liu, nanorobotics professors at Georgia Institute of Technology Chen Yongsheng and Wang Zhonglin, among others.[122]

Comparison of U.S. and Chinese Capabilities. While Japan and Germany are the global leaders in industrial robotics, the United States is home to several of the world's leading roboticists and maintains a technological lead in surgical robotics and collaborative robotics (i.e., robots that work in concert with humans).[123] In a 2016 report prepared for the Commission, the Defense Group, Inc. found that China's industrial robotics industry has rapidly increased production and research but remains plagued by a lack of talent, and high quality precise components.[124] The report noted that China is seeking to close these gaps through technology acquisition and investments, informal knowledge and technology transfers, and illicit technology acquisition such as cyber espionage or illegal exports.[125]

In sharp contrast to industrial robotics, China is the world's undisputed leader in commercial drones, with the Chinese firm Dajiang Innovation (DJI), accounting for around 70 percent of the global commercial drone industry in 2015.[126] DJI outcompetes its rivals based on its technological superiority, price, ability to use powerful commercial software applications, and customization.[127] U.S. commercial drone manufacturer 3D Robotics, formerly the world's second-largest commercial drone manufacturer, struggled to compete against DJI, and in August 2017, formed a partnership with DJI to supply their software to DJI's drones.[128]

Artificial Intelligence

Definition. AI—machine programs that can teach themselves by harnessing HPC and big data and eventually mimic how the human brain thinks—supports and enables nearly every sector of the modern economy.[129] AI is creating targeted marketing, safer travel through self-driving cars, smarter weapons, and new efficiencies in manufacturing processes, supply chain management, and agricultural production.[130] Corporations and governments are fiercely competing because whoever is the frontrunner in AI research and applications will accrue the highest profits in this fast-growing market and gain a military technological edge.

Industrial Policy. Aiming to make China the global leader in advanced AI, the 13th Five-Year Plan raised central-level backing for AI and laid out the objective to "facilitate commercial application of artificial intelligence technologies in all sectors."[131] In July 2017, the State Council released the Next-Generation Artificial Intelligence Development Plan that set a 2020 target for Chinese AI technology and applications to match international developments and a 2030 target for China to be at the forefront of international AI technology and application development with a domestic market valued at $147.7 billion (RMB 1 trillion).[132] Kai-Fu Lee, a former Microsoft and Google executive and currently chief executive at the venture capital firm Sinovation Ventures, noted that "China is poised to be a leader in AI because of its great reserve in AI talent, excellent engineering education, and massive market for AI adoption."[133]

In February 2017, the National Development and Reform Commission, China's industrial policy-making agency, approved plans to fund the development of a virtual national AI engineering lab for an undisclosed amount.[134] Led by Baidu, the lab will specialize in deep learning, computer vision and sensing, computer listening, biometric identification, and new forms of human-computer interaction.[135] Local governments have pledged more than $7 billion in

AI funding, and cities like Shenzhen are providing $1 million for AI start-ups.[136] By comparison, the U.S. federal government invested $1.1 billion in unclassified AI research in 2015 largely through competitive grants.[137] Due in part to Chinese government support and expansion in the United States, Chinese firms such as Baidu, Alibaba, and Tencent have become global leaders in AI.[138] Chinese firms also leverage U.S. talent and ecosystems to promote their development; for example, they:

- *Establish research institutes in the United States:* To access the talented engineers and scientists based in the United States, Baidu established two AI-related research facilities in Silicon Valley; Didi Chuxing, China's Uber, opened an AI and self-driving car research lab in Silicon Valley; and Tencent announced a new AI research center in Seattle.[139]
- *Invest in U.S. AI-related startups and firms:* From 2010 to 2016, Chinese firms have invested in at least 51 U.S. AI startups and firms.[140] Examples include: the Chinese venture capital firm Haiyin Capital's June 2016 investment into the AI unmanned system software developer Neurala (which had provided technology used by the U.S. Air Force and NASA); Baidu's April 2017 acquisition of the visual perception software and hardware firm xPerception; Tencent and several other Chinese investors' July 2017 investment in personal AI firm Oben; and Baidu's July 2017 acquisition of the AI language processing and comprehension firm Kitt.ai.[141]
- *Form commercial and academic partnerships:* In September 2015, the U.S. computer manufacturer Dell and the Chinese Academy of Sciences jointly established the Artificial Intelligence and Advanced Computing Joint Lab in China to develop cognitive systems and deep learning technologies.[142] In August 2016, Baidu formed a partnership with Nvidia to jointly develop a comprehensive autonomous driving platform, and in July 2017 agreed to collaborate on optimizing Baidu's deep learning framework.[143] In October 2016, Huawei and the University of California, Berkeley announced a strategic partnership focused on basic research in AI, with Huawei providing $1 million in funding.[144]
- *Recruit U.S.-based talent:* Chinese AI firms have hired U.S.-based talent to work at their U.S. research institutes or in China through programs like the Thousand Talents Program and Project 111, including world-renowned AI expert Andrew Ng,* former head of Google's deep learning and former Stanford University professor, Ya-qin Zhang, former head of Microsoft Corporation's Asian R&D operations, Qi Lu, former Microsoft executive vice president, and Yu Dong, a former Microsoft speech recognition and deep learning expert.[145]

*Mr. Ng led Baidu's artificial intelligence strategy and development until March 2017. He has since launched an online school to train AI students and professionals. Paul Mozur, "A.I. Expert at Baidu, Andrew Ng, Resigns from Chinese Search Giant," *New York Times*, March 22, 2017; Tom Simonite, "Andrew Ng Spreads the Gospel of AI with a New Online School," *Wired*, August 8, 2017.

Comparison of U.S. and Chinese Capabilities. U.S. and Chinese firms are seeking to gain a technological edge in AI research and application. The United States continues to lead in the number of AI patent applications, the number of AI firms, and the amount of funding provided, but China is quickly closing this gap.[146] Dr. Lee estimates U.S. firms have a two-year head start in driverless cars.[147] But in English and Mandarin speech recognition and synthetic speech, Baidu is becoming the market leader. In March 2017, Baidu's synthetic speech system, DeepVoice, converted text into an almost human-quality voice more than 400 times faster than Google's DeepMind, the world's previous leader.[148] While China's achievements are impressive, Dr. Lee noted that the most advanced research is still being done in the United States, with Chinese researchers dominating mid-level developments.[149]

Nanotechnology

Definition. Nanotechnology—the ability to utilize the physical, chemical, mechanical, and optical properties of individual atoms and molecules of automated devices at the nanoscale level*—is driving new developments in quantum information science, medicine, agriculture, energy, manufacturing, and defense, among other areas.[150] In health, nanoscale sensors enable molecular-level detection and treatment of disease while nanoscale molecular motors power novel drug delivery techniques and medical procedures for more precise treatment.[151] Analyzing big data using HPC is accelerating breakthroughs in nanotechnology R&D, commercialization of technology, and comprehensive risk assessments.[152]

Industrial Policy. Since 2000, the Chinese government has prioritized nanotechnology, rolling out massive government R&D and industry funding, recruiting overseas talent through its Thousand Talents Program, and creating nanotechnology science parks.[153] Nanotechnology funding from just one source—China's National Science Foundation Fund—increased nearly seven-fold from $90 million in 2004 to around $600 million in 2014.[154] By comparison, the U.S. National Nanotechnology Initiative, which coordinates federal nanotechnology R&D spending, reached an annual high of $1.9 billion in 2010 but since 2013, funding has not exceeded $1.5 billion per year.[155] Beyond R&D funding, the central and Suzhou municipal government in 2010 provided $886.3 million (RMB 6 billion) to construct Nanopolis Suzhou—one of China's nanotechnology science parks—with qualified nanotechnology start-ups eligible for millions in tax breaks, grants, subsidies for office rent and personnel salaries, and awards for sales revenue or patents.[156]

Comparison of U.S. and Chinese Capabilities. While China has become the fastest-growing country for nanotechnology publications and industrialization, particularly in nanomaterials and nanocomposites, the United States remains the technological leader in nanotechnology based on the number of firms involved

*Nanoscale refers to structures around 1 to 100 nanometers. A nanometer is one billionth of a meter. For comparison, a DNA molecule is 2–3 nanometers wide, and a human hair is generally 100,000 nanometers thick. U.S. National Nanotechnology Initiative, *What's So Special about the Nanoscale?*

in nanotechnology research, manufacturing, and applications; the amount of funding provided; the number of publications; and the number of citations its publications receive.[157] For example, the United States published 22,067 articles in the 20 leading nanotechnology journals from 2003 to 2013 compared with China at 3,421 articles.[158] According to Chinese researchers, low numbers of citations of research, poor communication between academic researchers and industry, lack of cross-regional R&D collaboration, and absence of clear nanotechnology standards are hindering further progress and creating potential quality control issues in research, allocation of funds, and production.[159] Patrick J. Sinko, professor at Rutgers University, noted an "immature venture funding market, intellectual property protection, technology transfer, and commercialization" as additional challenges for China's nanotechnology development.[160]

Biotechnology

Definition. The combination of big data, AI, HPC, and cloud computing storage with advances in genomics (the study of DNA structure, function, evolution, and mapping) and synthetic biology (the artificial design or modification of existing biological systems) are spurring the creation of entirely new medicines, food, energy, species, and diseases.[161] In healthcare, these advancements will lead to precision medicine (medical care based on an individual's biology, environment, and lifestyle).[162] But the speed of these developments is outpacing existing regulatory and ethical frameworks. Genetic and longitudinal * data—critical for future biotechnology breakthroughs—are not adequately protected nor granted reciprocal access globally.[163] At the same time, the gene editing tool CRISPR † is democratizing the ability to modify the genetic makeup of biologics such as plants, animals, and even humans, giving rise to ethical debates and fears of unintended consequences.[164]

Industrial Policy. Cao Xuetao, president of the Chinese Academy of Medical Sciences and Beijing Union Medical College, noted that the Chinese government is aggressively pursuing genomics and synthetic biology to improve the effectiveness of medical treatment and reduce overall medical costs through reducing the usage of unnecessary drugs.[165] In addition, by investing in genomics and synthetic biology, China hopes to leapfrog existing biotech firms and become a global leader.[166] The 13th Five-Year Plan seeks to strengthen China's leadership in biotechnology and precision medicine through:[167]

- *Funding genomics research:* The Chinese government provided $295.4 million (RMB 2 billion) for stem cell fundamental research under the 12th Five-Year Plan.[168] Between 2016 and 2020, it has allocated around $398.8 million (RMB 2.7

* Longitudinal data track environmental, lifestyle, and other factors and are used to identify genes dominant in specific behaviors and characteristics from the same source or sample over a period of time.

† CRISPR is short for Clustered Regularly Interspaced Short Palindromic Repeats. It is based on a bacterial immune system and is used to edit specific segments of the genetic code. Broad Institute, "Questions and Answers about CRISPR."

billion) for stem cell research projects, 10 percent of which will be allocated for gene editing.[169] Additionally, the Chinese government announced plans in 2015 to invest around $9 billion (RMB 60 billion) in precision medicine by 2030.[170] By comparison, the United States launched its own Precision Medicine Initiative in 2015 with only $215 million in initial investment.[171] Eric Schadt, director of the Icahn Institute of Genomics and Multiscale Biology at Mount Sinai, has expressed frustration "at how aggressively China is investing in this space while the [United States] is not moving with the same kind of purpose."[172]

- *Supporting Chinese firms:* In 2010, the China Development Bank provided a $1.58 billion line of credit to Beijing Genomics Institute (BGI), a private genome sequencing center, to buy 128 advanced DNA sequencing machines from the U.S. firm Illumina. With this purchase, BGI became the world's largest genetic sequencer, accounting for roughly a quarter of all DNA data sequenced in the world in 2014.[173] While BGI remains a global leader in genomic sequencing, it has since lost global market share due to competition—largely from other Chinese firms—and its failed attempt to market its own cutting-edge genomic sequencer in November 2015.[174] BGI is seeking to regain market share and unseat the global leader Illumina by developing a new genomic sequencer.[175]
- *Increasing the number of genome-related papers:* Chinese researchers have increased the number of genome-related papers they have published from 4.5 percent of the world's papers in 2010 to 17.3 percent by 2014.[176] In April 2015, Chinese scientists genetically modified the genomes of human embryos in order to cure a potentially fatal blood disorder called β-thalassaemia.[177] Although the team found that modifying one portion of a genome resulted in several unintended mutations in the genetic material, it was an important step forward in the field and pushed synthetic biologists to increase their DNA databases to study these mutations further and develop improved genetic sequencing technologies.[178] In October 2016, Chinese researchers began the world's first clinical trials to treat patients with advanced lung cancer with genetically modified immune cells.[179] In July 2017, U.S. researchers for the first time* edited the DNA of embryos to correct an incurable genetic heart defect without unintended genetic side effects.[180]
- *Expanding domestic access to DNA data:* Researchers can more accurately identify genes associated with specific diseases and study the impacts of genome modification (synthetic biology) by comparing an individual's genetics to large amounts of unique DNA data from a diverse population.[181] As a result, "whoever

*Unlike the Chinese government, the U.S. federal government is prohibited from financing embryo research, and the U.S. Food and Drug Administration cannot consider clinical trials with inheritable genetic modifications. In February 2017, the National Academies of Sciences, Engineering, and Medicine released guidelines on how human genome editing research should be conducted. Ariana Eunjung Cha, "First Human Embryo Editing Experiment in US Corrects Gene For Heart Condition," *Washington Post*, August 2, 2017; National Academies of Sciences, Engineering, and Medicine, *Human Genome Editing: Science, Ethics, and Governance*, February 2017.

has the largest, most diverse data sets of different populations wins the day" according to testimony from Ed You, supervisory special agent with the Federal Bureau of Investigation.[182] China's Ministry of Public Security already claims to have the world's largest DNA database—more than 40 million individuals—in part through forced DNA collection.[183] By comparison, the U.S. law enforcement DNA database of convicted offenders, detainees, and missing persons contained over 13 million individual profiles as of August 2017.[184]

- *Leveraging global partnerships:* Chinese firms are pursuing global partnerships, joint ventures, and investment opportunities to expand their access to diverse genetic data and longitudinal healthcare records, necessary for leading-edge biotechnology research. For example, BGI gained access to U.S. genetic health information after receiving accreditation from the College of American Pathologists in July 2015 and partnering on genome research projects run by Autism Speaks, Children's Hospital of Philadelphia, South Texas Accelerated Research Therapeutics, and the Allen Institute.[185] The Chinese state-owned life sciences investment firm WuXi Healthcare also has been accredited in the United States and contracted to carry out genetic sequencing and other diagnostic testing for U.S. citizens.* BGI's Chinese competitor, Novogene, established a genetic sequencing center at the University of California, Davis in April 2016 to provide U.S. customers and university faculty and scientists on-site sequencing services.[186] In September 2016, BGI launched the China National Genebank—initiated by the National Development and Reform Commission—a biorepository, bioinformatics center, and living biobank that seeks to store, read, understand, write, and apply genetic data.[187]

- *Attracting overseas talent:* The Chinese government has successfully attracted leading overseas academics and experts to move back to China, including Ge Li, founding scientist of Pharmacopeia Inc. and subsequently Wuxi AppTec, Inc., Samantha Du from Pfizer, Xiaodong Wang from University of Texas, and Steve Yang from AstraZeneca, among many others.[188] Kenneth Oye, professor at the Massachusetts Institute of Technology, highlighted the importance of Chinese and other foreign nationals studying in and immigrating to the United States in driving U.S. innovation, but noted that this advantage is declining "as educational programs, standards of living and research opportunities in China improve and more students choose to return to China."[189] For example, CRISPR was invented by Feng Zhang, a Chinese immigrant.[190]

- *Acquiring biotechnology firms:* Panelists Dr. Oye and Ben Shobert, founder of the healthcare consulting firm Rubicon Strategy Group, noted Chinese firms are acquiring biotechnology firms to gain ownership of key technology and intel-

*The College of American Pathologists, the State of California, and the U.S. Centers for Medicare and Medicaid have accredited Wuxi AppTec. Wuxi AppTec, "WuXi NextCODE Becomes the First and Only CAP, CLIA, and California Accredited Sequencing Laboratory in China," February 23, 2016.

lectual property and expand their global market access.[191] Based on data from Rhodium Group, in the last five years, China has invested more than $3.2 billion in the U.S. biotechnology and pharmaceutical sector.[192] Notable examples include BGI's 2012 acquisition of the U.S. genetic sequencing firm Complete Genomics, Humanwell Healthcare Group and PuraCap Pharmaceutical LLC's 2016 acquisition of the U.S. generic pharmaceutical manufacturer Epic Pharma, and iCarbonX's 2017 $100 million investment for a minority share in U.S. personalized medicine firm—the world's largest—PatientsLikeMe.[193]

Comparison of U.S. and Chinese Capabilities. Overall, U.S. biotechnology research and innovation remain ahead of China.[194] The United States continues to have the largest number of foundational science and clinical research articles published in high-ranking journals, accounting for nearly 37 percent of total articles in 2015 compared with China (ranked fourth) with 1.4 percent.* A review of the average number of citations per paper—a metric used to gauge a publication's impact—shows the United States has the highest, with an average of 35 citations per CRISPR-based paper followed by China at 21 and Japan at 7.5.[195] Mr. Shobert noted that this lead is due to the successful ecosystem the United States has built based on: strong foundational R&D funding; regulatory frameworks that incentivize biotechnology development and commercialization; a highly skilled workforce; close ties between government, universities, and the private sector; and robust venture capital funding.[196] Although China has sought to replicate this model, its regulatory system does not incentivize risk-taking innovation, and the government continues to spend a disproportionate amount more on biotechnology infrastructure over R&D.[197]

Implications for the United States

Although China's growing consumer market should present enormous opportunities for U.S. businesses, China's pursuit of dominance in emerging technologies is eroding U.S. technological and military advantages (see Table 4). Losing this advantage will weaken U.S. firms' competitive edge in high-value-added sectors of the economy and undermine the capabilities, capacity, and resilience of the U.S. defense industrial base. In his testimony before the Commission, Henrik Christensen, professor at the University of California, San Diego, noted that for the United States, "it's our opportunity to lose, but we need to react relatively quickly, both in terms of making sure that we control our innovation system, we maintain it here, we commercialize it here, and in terms of making sure that we have the right investments."[198]

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*This ranking is based on the number of publications in top-tier journals by single country authors. Marisa L. Conte et al., "Globalization and Changing Trends of Biomedical Research Output," *JCI Insight* 2017 2:12, 2.

Table 4: Current State of U.S. Technological Competition with China in Nine Sectors

U.S. Leads	Close Competition	China Leads
• Biotechnology • Nanotechnology • Cloud computing • Collaborative robots	• Artificial intelligence • Quantum information science • High performance computing	• Exascale computing • Commercial drones

Note: Factors that determine the state of technological leadership include: the number of firms, global market share, amount of R&D funding provided, the number of patent applications, the number of articles published in high-ranking journals, and the number of citations per publication. The status of technological leadership may shift due to changes in government policies or breakthroughs in R&D.

Source: This assessment is based on testimony received at the Commission's March 2017 hearing on China's pursuit of next-generation, dual-use technologies; contracted research; consultations with government officials, academics, and industry experts; and open source research and analysis.

China's state-directed industrial policies are slowly closing market opportunities for U.S. and other foreign firms in China and nurturing Chinese competitors that will be able to challenge U.S. companies in the United States and in third country markets. In contrast, Chinese firms have been able to leverage the openness of the United States to gain access to its advanced research and data, recruit its talented workforce, acquire and invest in leading edge U.S. firms, and freely sell their products and services here.

Close integration between Chinese civilian and military entities raises concerns that technology, expertise, and intellectual property shared between U.S. firms and Chinese commercial partners could be transferred to China's military.[199] The 13th Five-Year Plan reaffirmed the state's long-held commitment to integrating civilian and military technology development, stating that the Chinese government seeks to "encourage flow of factors such as technology, personnel, capital, and information between the economic and defense sectors" and strengthen the "coordination between the military and civilian sectors in the sharing of advanced technologies, industries, products, and infrastructure."[200] For cutting-edge sectors such as AI, robotics, and biotechnology, commercial entities rather than the military are increasingly driving global R&D breakthroughs, making access to the most advanced technology harder to control.[201] In January 2017, the Chinese Communist Party created the Central Commission for Integrated Military and Civilian Development to deepen this coordination. The Commission is led by Chinese President and General Secretary of the Chinese Communist Party Xi Jinping and met for the first time in June 2017.[202]

High-Performance Computing

"Continued U.S. leadership in high performance computing is essential to our security, prosperity, and economic competitiveness as a nation," noted Secretary of Energy Rick Perry.[203] U.S. national laboratories fund the development of the most advanced supercomputers and their applications that are later incorporated into the commercial sector, providing a competitive advantage in R&D.[204] China's policies aim to reduce the country's dependence on imports of HPC and develop domestic champions through preferential procurement policies and substantial R&D investment.[205] These policies have not only cut U.S. firms out of the Chinese market, but also are limiting the effectiveness of U.S. export controls and eroding the United States' technological edge in advanced computing.[206] A December 2016 report by the National Security Agency and the Department of Energy reiterated this concern, stating that "absent aggressive action by the U.S.—the U.S. will not control its own future in HPC," and that this "loss of leadership in HPC will severely compromise our national security."[207] For example, the Department of Defense, National Security Agency, and National Nuclear Security Administration rely on access to the most advanced computing for cryptography, weapons testing, and certification of the country's nuclear deterrent. Since these agencies cannot buy these capabilities from overseas, the loss of U.S. leadership in advanced HPC would have direct implications on future strategic deterrent and warfare capabilities.[208]

Cloud Computing

Beijing's restrictive policies in cloud computing are cutting U.S. firms out of China's growing market in violation of its WTO commitments. Opportunities for U.S. firms are expected to shrink over the next decade as China develops its own indigenous cloud computing hardware and software and expands abroad.[209] In addition, Chinese cloud computing firms' close ties to the Chinese government raise security concerns over the protection of sensitive data such as intellectual property within China and the potential for the government to request access to sensitive data from global customers.[210] The American Chamber of Commerce in China stated in November 2016 that China's restrictions on cross-border data transfers "provide no security benefits," and components of the Cybersecurity Law "will unnecessarily weaken security and potentially expose personal information."[211]

Quantum Information Science

Remaining at the forefront of quantum information science is critical for U.S. economic competitiveness, leadership in scientific discovery, and national security.[212] If fully operationalized, this next generation of IT will transform existing computing, communication, encryption, and defense technologies and capabilities. Economically, the frontrunner in quantum information science will gain global market dominance, creating numerous jobs and spurring economic growth.[213] Leadership in quantum information science also would have enormous national security benefits stemming from near unbreakable communication security and potential satellite and radar technology developments.[214]

Robotics

China's development of its industrial and military robotics sector is strengthening the quality and competitiveness of China's manufacturing, military capabilities, intelligence collection, and power projection. As high-value-added products incorporate more embedded computers and advanced sensors and tailor to individual customer demands, automated production is becoming a necessity.[215] U.S. high-tech firms have utilized automated production to make higher-quality and higher-value-added products. As China enhances its own automated manufacturing, competition for U.S. firms will increase. In addition, the inherent functions of industrial robotics improve the manufacturing quality and productivity of military equipment such as tanks or fighter jets.[216]

Unmanned systems such as drones and self-driving cars are redefining transportation, delivery, construction, agriculture, research, entertainment, and warfare. Leaders in this field will establish market dominance and drive future commercial and military technological innovation. For the military, unmanned systems are an important component in the U.S. Third Offset strategy,* which seeks to counter Russian and Chinese advancements in antiaccess/area denial (A2/AD) capabilities and cyber and electronic warfare with new technological advances in deep learning, collaborative robotics, nanotechnology, and autonomous systems.[217]

Artificial Intelligence

While Chinese firms' robust engagement with the U.S. AI community is creating jobs, funding startups, and contributing to new research discoveries, China's industrial policies raise U.S. concerns about fair competition, market access in China, and the role of investments and the potential spillovers from innovative AI research in advancing China's military capacity. The global market for AI-based systems is expected to grow to around $153 billion by 2020, with $83 billion in robotics and $70 billion for AI-based analytics, according to projections from Bank of America Merrill Lynch.[218] The Made in China 2025 Key Area Technology Roadmap aims to increase the domestic market share of Chinese-branded smart manufacturing products to over 60 percent by 2025 and Chinese-branded driver-assisted, partially autonomous vehicles to exceed 50 percent by 2025.[219] Reaching these localization targets would close China's growing market to U.S. and other foreign firms, a major loss of future market and job opportunities.

In May 2017, Daniel R. Coats, Director of National Intelligence, warned that AI advancements in countries such as China could increase the United States' vulnerability to cyber attacks, weaken its ability to attribute such attacks, improve the effectiveness and capabilities of foreign weapon and intelligence systems, create new accident and related liability issues, and reduce employment.[220] In addition, maintaining the U.S. military's edge is becoming increasingly difficult. Elsa Kania, former analyst at the Long Term Strategy Group, found that AI's dual commercial and military application and the private sector's role in driving pioneering research make controlling the transfer and spread of dual-use breakthroughs from the United States to its competitors difficult.[221]

Nanotechnology

The dual-use applicability of nanotechnology has important implications for the global competitiveness of U.S. IT, healthcare, agricul-

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*The U.S. Third Offset strategy seeks to maintain U.S. technological leadership by developing cutting-edge technologies that will meet future U.S. military requirements and counter advancements by adversaries.

ture, energy, and defense industries.[222] The United States achieved its global leadership in nanotechnology in part due to coordinated federal R&D funding appropriations through the National Nanotechnology Initiative.[223] In his testimony, Dr. Sinko cautioned that "reductions in nano funding would not only lead to reduced global competitiveness in areas such as healthcare, science and technology, and other industries, but also could have serious implications on national defense as more than 60 countries have national nanotechnology development programs with their eye on dual-use technologies."[224]

Biotechnology

Despite pressuring China at the U.S.-China Joint Commission on Commerce and Trade and WTO, U.S. and other foreign biotechnology firms continue to face a slow drug approval process, exclusion from China's drug reimbursement system, intellectual property theft, and preferential treatment for Chinese firms.[225] For example, China's state-directed policies subsidized the establishment of the world's largest genomic sequencing firms.[226] This support allows Chinese firms to provide genomics sequencing services at a fraction of the price and speed of U.S. and other foreign genomic sequencing firms, leading U.S. researchers and healthcare facilities to contract with Chinese firms for genetic sequencing and diagnostic processing.[227] While this cheaper processing has accelerated disease research, health diagnostics, and genealogy studies, Mr. You cautioned that this shift has raised new security concerns, including:

- *Regulatory gaps in data privacy:* The Health Insurance Portability and Accountability Act of 1996 (HIPAA) strictly regulates the storage and transfer of personal healthcare data to ensure its security and privacy.[228] However, HIPAA only applies to data collected, stored, or sent by or to healthcare providers and their business associates, healthcare insurance firms, or medical billing clearing houses (see Table 5 for a summary of what data HIPAA protects).[229] Individuals who send their data to new health-related services (such as genetic testing firms) or through their wearable devices are generally not covered under HIPAA.[230] In addition, greater computing power and access to massive amounts of publicly available data on individuals makes it possible to re-identify individuals from de-identified healthcare data—even if the data have been anonymized per HIPAA regulations.[231] In particular, the ability to re-identify individuals combined with the lack of protections for genetic data held by entities not covered by HIPAA have raised concerns among U.S. data privacy advocates over data privacy protections and legal recourse for misuse.[232] If these data are transferred overseas, U.S. agencies such as the Department of Justice, the Federal Bureau of Investigation, and the Department of Health and Human Services may have difficulty conducting investigations and imposing penalties on entities located abroad for HIPAA violations.[233]

Table 5: Data Covered under HIPAA Protections

Covered by HIPAA	Covered only if conducted by HIPAA-covered entity	Not Covered by HIPAA
Data collected, stored, or sent by or to HIPAA-covered entities (healthcare providers and their business associates, healthcare insurance firms, or medical billing clearing houses)	Personal healthcare records	All de-identified health-related data
	Clinical data	Healthcare or other data, such as DNA or longitudinal data, sent by individuals to entities not covered by HIPAA, including some genetic testing service firms or precision medicine firms
	Diagnostic processing	Data collected, stored, or sent by or from health-related wearable devices not prescribed by your doctor or from entities not covered by HIPAA

Source: U.S. Department of Health and Human Services, Office of Civil Rights, interview with Commission staff, September 12, 2017.

- *Theft of healthcare data for their future value:* Healthcare records and clinical data are not adequately valued or protected for their future role in driving new biotechnology developments.[234] When large amounts of DNA data are combined with longitudinal data from healthcare records, researchers can more accurately account for the genetic, lifestyle, or environmental causes of a disease and guide treatment decisions.[235] The number of cyber attacks against these weakly protected institutions is growing due to the value of these data for fraudulent activity and R&D.[236] In the past few years, systems of U.S. health providers have been penetrated multiple times by perpetrators traced to China. For example, Anthem, which had nearly 80 million patient records hacked in February 2015, and Premera Blue Cross, which had 11 million patient records hacked in March 2015, both attributed their attacks to China-based groups.[237] Beyond health and genetic data, hackers also can gain insight into expensive and time-intensive clinical tests, potentially allowing them to produce new medicines and technologies at a fraction of the cost.

- *Lack of data access reciprocity:* Big data, HPC, and AI are critical for discovering new breakthroughs in medical diagnostics, medicines, and synthetic biology, but Chinese regulations severely limit U.S. access to China's data, disadvantaging U.S. researchers, academics, and firms.[238] For example, China's data localization and cross-border data transfer restrictions compel foreign firms to establish joint venture data storage centers in China to store their data and limit the ability of firms and researchers to combine their China-based data with their global databases.[239] By comparison, Chinese firms are expanding their access to diverse genetic information through U.S. acquisitions, accreditation, and contracts to carry out genetic sequencing and other diagnostic testing for U.S. citizens.[240]

- *Speed, scale, and complexity of biotechnology developments outpace regulations:* According to a March 2017 study by the National Academies of Sciences, Engineering, and Medicine, the rapid increase in number, complexity, and range of biotechnology products and breakthroughs will likely outpace existing U.S. government capacity, regulatory risk-assessment processes, and governance systems.[241]
- *Creation of new harmful or hazardous biological agents:* The quick pace of new developments, low cost of genetic sequencing, and the rapid diffusion of technologies and techniques have driven major advancements in the production of microbial genomes and new pharmaceutical production methods, leading to new risks from malevolent or unintentional misuse and outdated regulatory and ethical frameworks.[242] In addition, China—the world's largest pharmaceutical ingredient manufacturer and exporter and home to the world's largest genomic sequencing firms—may be a major source of risk.[243] Its chemical and pharmaceutical industries are weakly regulated and monitored and ill equipped to prevent illegal activity in emerging biotechnology areas.[244]

Addendum I: China's Industrial Policies in Five Strategic Sectors

	High-Performance Computing	**Cloud Computing**	**Industrial Robotics**	**Autonomous Systems**	**Biotechnology**
Major Policy Documents	Made in China 2025 13th Five-Year Strategic Emerging Industries Development Plan	Made in China 2025 Internet Plus National Informationization Development Strategy (2006–2020) 13th Five-Year Strategic Emerging Industries Development Plan Cloud Computing Development Three-Year Action Plan (2017–2019)	Made in China 2025 Internet Plus 13th Five-Year Strategic Emerging Industries Development Plan Robotics Industry Development Plan (2016–2020)	Made in China 2025 Internet Plus 13th Five-Year Strategic Emerging Industries Development Plan Robotics Industry Development Plan (2016–2020) "Internet Plus" Artificial Intelligence Three-Year Action Plan Next-Generation Artificial Intelligence Development Plan	Made in China 2025 Internet Plus 13th Five-Year Strategic Emerging Industries Development Plan 13th Five-Year Bioindustry Development Plan 13th Five-Year Medical Industry Development Plan Healthy China 2030
Regulations	National Security Law Counterterrorism Law Cybersecurity Law	National Security Law Counterterrorism Law Cybersecurity Law	Minimal impact from regulations	Cybersecurity Law	Anti-Monopoly Law Cybersecurity Law National Reimbursed Drug List Administrative Provisions for Drug Registration

Addendum I: China's Industrial Policies in Five Strategic Sectors—*Continued*

	High-Performance Computing	**Cloud Computing**	**Industrial Robotics**	**Autonomous Systems**	**Biotechnology**
Select Localization Targets	Supercomputers: 60 percent by 2020; 80 percent by 2025	Financial services and telecommunications computer servers: 75 percent by 2020; 90 percent by 2025 Financial services and telecommunications basic software: 50 percent by 2020; 75 percent by 2025	Industrial robotics: 50 percent by 2020; 70 percent by 2025 Robotic core components: 50 percent by 2020; 70 percent by 2025	Driver-assisted, partially autonomous automobiles: 40 percent by 2020; driver-assisted, partially autonomous, and highly autonomous automobiles: 50 percent by 2025	Advanced medical devices: 50 percent by 2020; 70 percent by 2025
China-specific standards	Technical standards "secure and controllable" requirements	Technical standards Data localization Cross-border data restrictions "secure and controllable" requirements	Technical standards	Technical standards Extensive censorship requirements Cross-border data restrictions	Technical standards Data localization Cross-border data restrictions
Foreign investment restrictions and import guidance	Catalogue on Guiding Foreign Investment Catalogue on Encouraged Imported Technology and Products				
National champions	Lenovo Sugon Inspur Huawei	Alibaba China Telecom Tencent Huawei	Siasun Harbin Boshi Automation	Baidu Dajiang Innovation	BGI Wuxi Healthcare Ventures

Source: Compiled by Commission staff from Chinese government sources, industry reports, and testimony.[245]

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