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China's S&T and Innovation Efforts

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My name is Dean Cheng. I am a Senior Research Fellow in the Asian Studies Center at The Heritage Foundation. The views I express in this testimony are my own and should not be construed as representing any official position of The Heritage Foundation.

Over the past forty years, since Deng Xiaoping began his policy of "Reform and Opening," the People's Republic of China (PRC) has evolved from a less developed country to the second largest gross domestic product (GDP) in the world. Over the past 25 years, it has also steadily transformed the People's Liberation Army (PLA) into a force that is capable of influencing regional, and increasingly global, security environments.

An essential element of this growth, both in terms of China's economy and military, rests upon its ongoing investments and support for science and technology, including in critical technology areas.

A Long-standing Emphasis on Science and Technology (S&T)
Chinese leaders have long viewed science and technology as an essential part of China's "comprehensive national power (*zonghe guojia liliang*; 综合国家力量)." Comprehensive national power reflects the various factors that influence a nation's capabilities and international standing. It includes national military and economic strength, political unity, and diplomatic standing. An essential element of comprehensive national power is the nation's level of scientific and technological development.

By Beijing's Chinese calculations, a capable scientific and technological base is essential in order to achieve economic autonomy. A state that has substantial capabilities in this regard, they believe, can chart its own course, determining what kinds of industries it will develop. Moreover, it can reap significantly better returns on its investments, by moving higher up the value chain. By contrast, a nation with a weak scientific and technological base will likely be relegated to subcontracting to other states, and will find it hard to break into those areas with better returns on investment.

At the same time, science and technology are increasingly linked to military capacity. While militaries in the Industrial Age could rely on mass to overwhelm an adversary, in the Information Age, it is quality, as well as quantity, that matters. Chinese military and political leaders, analyzing the conflicts since the first Gulf War (1990–1991), have clearly concluded that the PLA can no longer rely on barely trained militia equipped with "rifles and millet" as they did during the Mao Zedong era. Instead, they have focused on developing ever more sophisticated weapons in order to "fight and win future informationized local wars."

To this end, Chinese leaders have consistently supported programs that promote the PRC's scientific and technological capacity and support innovation.

Deng Xiaoping put in place "Plan 863," also known as the Program for High-Technology Research and Development. In March 1986, four leading Chinese scientists (who were also part of the military industrial complex) approached Deng, and urged him to support investments in high technology. Only by increasing China's scientific base, they argued, could the PRC hope to compete in the long term with the Soviet Union and the West. Deng authorized the creation of Plan 863, which directed investments of human, physical, and financial capital towards seven key high-technology areas:

1) Automation,
2) Biological sciences and genetic engineering,
3) Energy,
4) Information technology,
5) Lasers,
6) Advanced materials, and
7) Aerospace technology.[1]

Thirty years later, Plan 863 continues to support advanced research in these areas, as well as telecommunications and marine sciences (which were added to Plan 863's purview in the 1990s).

Under *Jiang Zemin*, who became Party General Secretary and national leader in 1992, the PRC began to push investments in interdisciplinary research under "Plan 973," also known as the National Basic Research Program of China. While oriented more towards basic (rather than applied) research, it supported a variety of efforts. Jiang also put in place two major programs ("Plan 985" and "Plan 211") to improve China's universities to world-class standards. As China produces tens of thousands of engineers and scientists every year, many of these are likely to have benefited from the additional resources allocated to these universities.

Hu Jintao made "indigenous innovation" one of his signature catch phrases. During Hu Jintao's administration (2002–2012), the PRC issued the "National Medium to Long-Term Plan for the Development of Science and Technology." This called for China to become a major source of global innovation by 2020, allocating 2.5 percent of GDP to research and development. The Medium to Long-Term Plan includes an array of engineering and scientific megaprojects, as well as "frontier technologies" which align with those previously enumerated as part of Plan 863.

[1]Micah Springut, Stephen Schlaikjer, and David Chen, *China's Program for Science and Technology Modernization: Implications for American Competitiveness* (Washington, DC: Government Printing Office, 2011), p. 27, http://sites.utexas.edu/chinaecon/files/2015/06/USCC_Chinas-Program-for-ST.pdf (accessed January 5, 2018).

Table I-1 Key Areas, Technologies, and Programs Identified in China's Medium- and Long-Term Plan for Development of Science and Technology[*]

Key Areas (11):	**Frontier Technologies (8):**
• Agriculture • Energy • Environment • Information technology industry and modern services • Manufacturing • National defense • Population and health • Public securities • Transportation • Urbanization and urban development • Water and mineral resources	• Advanced energy • Advanced manufacturing • Aerospace and aeronautics • Biotechnology • Information • Laser • New materials • Ocean
Engineering Megaprojects (16):	**Science Megaprojects (4):**
• Advanced numeric-controlled machinery and basic manufacturing technology • Control and treatment of AIDS, hepatitis, and other major diseases • Core electronic components, high-end generic chips, and basic software • Drug innovation and development • Extra-large-scale integrated circuit manufacturing and technique • Genetically modified new-organism variety breeding • High-definition Earth observation systems • Large advanced nuclear reactors • Large aircraft • Large-scale oil and gas exploration • Manned aerospace and Moon exploration • New-generation broadband wireless mobile telecommunications • Water pollution control and treatment	• Development and reproductive biology • Nanotechnology • Protein science • Quantum research

During Hu's administration, the Chinese Academy of Sciences, a key part of China's research and scientific organizational infrastructure, also released a massive series of reports highlighting key Chinese technology targets by 2050. These included energy, aerospace technologies, advanced manufacturing, advanced materials, information technology, and oceanographic research.[2] Hu also encouraged foreign direct investment—and also often required high-technology industries to open research campuses in China as part of those investments.

Under *Xi Jinping*, this emphasis on science and technology and innovation has continued unabated. In February 2016, a new key high-technologies program was announced. This would merge several ongoing programs, including Plan 863 and Plan 973, and reorganize them into five lines of effort.[3]

1) Natural sciences,

[*]From U.S. National Research Council, *The New Global Ecosystem in Advanced Computing: Implications for U.S. Competitiveness and National Security* (Washington, DC: The National Academies Press, 2012), p. 102.

[2]China Academy of Sciences, *Innovation 2050: Science, Technology, and China's Future* (Beijing, PRC: Science Publishing House, 2009).

[3]"China Inaugurates National R&D Plan," *Xinhua*, February 16, 2016, http://news.xinhuanet.com/english/2016-02/16/c_135104108.htm (accessed January 5, 2018).

2) Major science and technology projects,
3) Key technologies R&D plan,
4) Technical innovation, and
5) Human resources for science and technology.

China's S&T and Innovation Players

These various programs have supported efforts by an extensive cross-section of Chinese institutions, reflecting not simply a ***whole-of-government*** approach to promoting science and technology, but a ***whole-of-society*** approach. The Chinese have employed all the various tools at their disposal, from their own substantial human capital to business deals to economic espionage, to foster and improve their scientific and technological prowess. Most important, arguably, has been the massive array of domestic research institutes and entities. These include:[4]

The Chinese Academy of Sciences. With a staff of some 50,000 and an array of 100 subordinate institutions, this is the leading institution of Chinese scientific endeavors.

Government Research Institutes. The various governmental ministries have their own research institutes, which provide more focused research on topics related to their areas of specialization.

Institutions of Higher Education. As noted earlier, Jiang Zemin began a program to improve China's universities and elevate them to world-class status as research institutions. This has been concomitant with a major expansion of China's scientific human capital. One research report concludes that China is the world's foremost producer of undergraduates with degrees in science and engineering, representing one-quarter of the global annual output. The report also concludes that the PRC produces more doctorates in natural sciences and engineering than any other nation.[5]

Industrial Enterprise Research Entities. This includes both research at state-owned enterprises (SOEs) and that at privately run corporations. For certain key sectors, such as aerospace, the supporting industries are still SOEs. One example is the Chinese Aerospace Science and Technology Corporation (CASC), which is one of the two main conglomerates in China's space industrial complex. CASC is a massive entity, with 90,000–120,000 employees and eight subordinate academies. Each of these academies, in turn, has an array of research laboratories and institutes, and some even have their own universities.

Not all Chinese research is conducted through state-owned or state-directed enterprises, however. Chinese *private companies* are increasingly part of the landscape of Chinese science and technology. In October 2017, Jack Ma, perhaps China's wealthiest man and head of the private company Alibaba, announced that his company would be investing ***$15 billion*** over the next three years in a massive R&D push. This would include "projects in areas such as data intelligence, financial technologies, quantum computing, and machine learning."[6]

The Alibaba research initiative reflects China's growing economic clout. Chinese authorities recognize that many companies desire to be part of the Chinese market, and have therefore taken advantage of this to access key

[4]This section draws from Micah Springut, Stephen Schlaikjer, and David Chen, *China's Program for Science and Technology Modernization: Implications for American Competitiveness* (Washington, DC: Government Printing Office, 2011), pp. 18–22, http://sites.utexas.edu/chinaecon/files/2015/06/USCC_Chinas-Program-for-ST.pdf (accessed January 8, 2018).

[5]Reinhilde Veugelers, *The Challenge of China's Rise as a Science and Technology Powerhouse*, Bruegel Policy Contribution No. 19, July 2017, http://bruegel.org/wp-content/uploads/2017/07/PC-19-2017.pdf (accessed January 5, 2018).

[6]Saheli Choudhury, "Alibaba Says It Will Invest Over $15 Billion Over Three Years in Global Research Program," CNBC, October 11, 2017, https://www.cnbc.com/2017/10/11/alibaba-says-will-pour-15-billion-into-global-research-program.html (accessed January 5, 2018).

technologies. Chinese authorities have welcomed foreign direct investment in the PRC—but foreign companies are generally required to form joint ventures with Chinese partners, who in turn will have access to key processes and intellectual property. The ability even to form a joint venture is often predicated upon the willingness to transfer technology, processes, or patents to the PRC.

Augmenting these various open efforts has been an extensive economic espionage program. This has included the use of PLA assets to acquire information and technology. The indictment of five Chinese military officers in 2014 by the U.S. Department of Justice was not for military spying, but for "computer hacking, economic espionage, and other offenses directed at six American victims in the U.S. nuclear power, metals, and solar products industries." The officers were specifically accused of stealing information "that would be useful to their competitors in China, including state-owned enterprises."[7]

Expanding Payoffs
These various efforts have already begun to bear significant fruit. From being primarily reliant on foreign technology, Chinese scientists have scored a number of major innovations and successes in recent years. These include achievements in:

Genetic Engineering. Chinese scientists have been the first to conduct human trials involving cells modified through Clustered Regularly Interspaced Short Paindromic Repeats (CRISPR) gene-editing technology. This includes a case involving aggressive lung cancer,[8] and another involving editing cloned human embryos with genetic diseases.[9]

Space Systems. China will launch a lunar lander to the far side of the Moon in 2018, something neither Russia nor the United States have done before (despite much more extensive lunar exploration programs). In order to support this mission, the Chinese are also deploying a data-relay satellite to Lagrange Point-2, one of the five points in the Earth-Moon-Sun system where the various gravitational fields create "parking spots." While a number of nations have deployed scientific satellites to various Lagrange points, China will launch the first data-relay satellite to such a location in 2018, in support of its pioneering far-side lander mission.[10]

China has also deployed the first quantum computer on a satellite, launching Micius in August 2016. In August 2017, they used the quantum satellite to transmit data 1200 kilometers, an unprecedented distance.[11] This was followed in September 2017 with a videophone call from Beijing to Vienna, which was encrypted using keys generated on the satellite.[12]

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[7]News release, "US Charges Five Chinese Military Hackers for Cyber Espionage Against US Corporations and Labor Organization for Commercial Advantage," U.S. Department of Justice, May 19, 2014, http://www.justice.gov/opa/pr/us-charges-five-chinese-military-hackers-cyber-espionage-against-us-corporations-and-labor (accessed January 5, 2018).

[8]David Cyranoski, "CRISPR Gene-Editing Tested in a Person for the First Time," *Nature*, November 15, 2016, https://www.nature.com/news/crispr-gene-editing-tested-in-a-person-for-the-first-time-1.20988 (accessed January 5, 2018).

[9]David Cyranoski, "Chinese Scientists Fix Genetic Disorder in Cloned Human Embryos," *Nature*, October 2, 2017, https://www.nature.com/news/chinese-scientists-fix-genetic-disorder-in-cloned-human-embryos-1.22694 (accessed January 5, 2018).

[10]Leonard David, "China Launching Lander, Rover to Moon's Far Side This Year," Space.com, January 4, 2018, https://www.space.com/39275-china-change-4-moon-mission-launch-2018.html (accessed January 5, 2018).

[11]Arjun Kharpal, "China Uses a Quantum Satellite to Transmit Potentially Unhackable Data," CNBC, August 10, 2017, https://www.cnbc.com/2017/08/10/china-uses-quantum-satellite-to-transmit-potentially-unhackable-data.html (accessed January 5, 2018).

[12]Amy Nordrum, "China Demonstrates Quantum Encryption By Hosting a Video Call," *IEEE Spectrum*, October 3, 2017, https://spectrum.ieee.org/tech-talk/telecom/security/china-successfully-demonstrates-quantum-encryption-by-hosting-a-video-call (accessed January 5, 2018).

Information Technology. China's advances in quantum computing are part of a larger effort that has seen China rise to the top in certain key areas of information technology. China, for example, has the world's fastest and second fastest super-computers (Sunway TaihuLight and Tianhe-2, respectively); the fastest U.S. supercomputer ranks fifth.[13] It should also be noted that the Sunway TaihuLight uses ***only*** Chinese-manufactured microprocessors, reflecting the maturing of China's microprocessor industry.[14]

Chinese leaders have meanwhile echoed Vladimir Putin in emphasizing the need to develop artificial intelligence (AI). In July 2017, Beijing issued the "New Generation Artificial Intelligence Plan," outlining China's goal to become a major center for artificial intelligence research and applications by 2030. Alibaba and Baidu, the Chinese search engine, are meanwhile pushing development of AI.[15] In this regard, the massive Chinese censorship infrastructure they have put in place, including the Great Firewall of China, is likely to be a major facilitator in this effort. To some extent, Chinese censors already rely on AI as an initial filter to screen messages for acceptability. This trend will likely accelerate, as China puts in place the "social credit score" which will take even more factors into account—and require even more monitoring.

Drone Technology. Chinese drones span the gamut of sophistication and capability. At one end are dedicated military drones such as the CH-3, CH-4, and CH-5. These resemble American unmanned combat aerial vehicles (UCAVs) such as the Reaper and Predator. In this area, Chinese engineers have deployed an experimental drone to 82,000 feet, substantially higher than the U.S. military's RQ-4 Global Hawk, which had been the previous high flyer at 60,000 feet.[16]

At the other end, Dajiang Innovation Technology Corporation (DJI) dominates the consumer drone market. It apparently also collected audio, visual, and telemetry data from its hundreds of thousands of drones used around the world. This has become such a concern that the U.S. Army banned the further use of DJI drones in August 2017.[17]

These various advances highlight the increasing synergies among Chinese high-technology efforts. Advances in artificial intelligence help improve drone performance, while the drones themselves provide potential access to tens of thousands of data feeds. Advances in information technology are at the heart of the recent advances in genetic engineering.

The Growing Challenge from Chinese Science, Technology, and Innovation

This brief survey of Chinese technological advances provides a glimpse to the extent of the growing challenge the PRC poses to U.S. technological and scientific preeminence. Indeed, in some areas such as super-computing, it is

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13 Top500 List, November 2017, https://www.top500.org/list/2017/11/ (accessed January 5, 2018).

14 Patrick Thibodeau, "China Builds World's Fastest Supercomputer Without US Chips," *Computerworld*, June 20, 2016, https://www.computerworld.com/article/3085483/high-performance-computing/china-builds-world-s-fastest-supercomputer-without-u-s-chips.html (accessed January 5, 2018).

15 Louise Lucas, "Chinese Tech Groups Look for Edge in Using Artificial Intelligence," *Financial Times*, December 18, 2017, https://www.ft.com/content/e8bba054-d02f-11e7-b781-794ce08b24dc (accessed January 5, 2018), and Anthony Kuhn, "Chinese Advances in Artificial Intelligence," NPR, January 1, 2018, https://www.npr.org/2018/01/01/574985930/chinese-advances-in-artificial-intelligence (accessed January 5, 2018).

16 Stephen Chen, "China Tests New Spy Drones in Near Space 'Death Zone,'" *South China Morning Post*, October 31, 2017, http://www.scmp.com/news/china/society/article/2117709/china-tests-new-spy-drones-near-space-death-zone?utm_source=edm&utm_medium=edm&utm_content=20171031&utm_campaign=scmp_china&emarsys=1&sc_src=email_2060322&sc_llid=1157&sc_lid=146777614&sc_uid=CdSb7QuJVI (accessed January 5, 2018).

17 Bart Jansen, "Army Bans DJI Drones Because of Concerns about Cyber Vulnerabilities," *USAToday*, August 4, 2017, https://www.usatoday.com/story/news/2017/08/04/report-army-bans-dji-drones-because-concerns-cyber-vulnerabilities/540720001/ (accessed January 5, 2018).

China, not the United States, that is the leader. It is therefore essential that the United States government, including Congress, recognize the nature of the challenge posed by Beijing's science and technology juggernaut.

First, *the PRC is not reliant on stealing technology; it is increasingly an innovator*. China may benefit from reduced R&D costs by engaging in economic and scientific espionage, but the growing number of "firsts" that it has scored, whether in deploying a lander to the far side of the Moon or a quantum communications satellite that can support video telephone calls across continents, should dispel the belief that it is wholly dependent upon exploiting others' innovations. Indeed, the Chinese themselves have emphasized that they do not want to rely on outside technology—as seen with the Sunlight TaihuLight super-computer.

Second, *China is competing with its entire society*. That the PRC has employed its military cyber forces to engage in espionage is already well known. But China's actions go beyond having the military help its economic competitiveness. It is also important to recognize that civilian and nongovernmental entities, in turn, are likely to help military and security efforts. This apparent integration of civilian and military efforts, at least in the realm of computer network operations, is supported by the observation in the 2013 edition of *The Science of Military Strategy* that there are three broad categories of Chinese computer network warfare forces. These are comprised of:

1) Specialized military units, specifically tasked for implementing network offensive and defensive operations;
2) Specialist units organized with military permission, drawn from local capabilities (e.g., from within a military region or war zone), including the Ministry of State Security and the Ministry of Public Security, and other relevant government departments; and
3) Civilian strength, comprised of voluntary civilian participants who can conduct network operations after being mobilized and organized.[18]

The PRC government is also likely to *draw upon the resources and personnel of Chinese private companies*. As a Council on Foreign Relations conference report warned, U.S. policymakers should view many Chinese private-sector firms as essentially operating at the behest of the PRC government. "There is little functional distinction between private firms and…[state-owned enterprises], one participant noted; another underscored the role that Chinese state financing plays in lending a political overtone to what might otherwise appear to be private-sector investment decisions."[19]

Finally, it is important to recognize that *the PRC's efforts at promoting science and technology, and innovation more broadly, encompasses a variety of approaches*. The American focus is typically on technological innovation; what new widgets might be on the horizon? But there are other forms of innovation. During the 1980s, when there was great concern about Japan's challenge to the United States, it was recognized that companies like Sony and Honda were competing, not by making entirely new things, but by improving how things were made. While the VCR was invented in the United States, it was Japanese companies that manufactured them by the commercial container-load cheaply yet reliably. Japanese production techniques were the innovation.

Similarly, there can be doctrinal and organizational innovation. In 1940, Great Britain and France both fielded more tanks than Nazi Germany. Moreover, many of the Allies' tanks were arguably superior to their German counterparts, on a 1:1 basis. But the Germans had developed the doctrine of *blitzkrieg*, and organized their forces accordingly, whereas the Allies remained wedded to a doctrine that largely saw tanks as subordinate to the infantry, to be dispersed across the front.

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[18]Academy of Military Science Military Strategy Research Office, *The Science of Military Strategy* (Beijing, PRC: Military Science Publishing House, 2013), p. 196.

[19]Council on Foreign Relations, "Chinese Investment in Critical US Technology: Risks to US Security Interests," October 16, 2017, https://www.cfr.org/report/chinese-investment-critical-us-technology-risks-us-security-interests (accessed January 5, 2018).

Taken together, technological, production, doctrinal, and organizational innovation presents the potential of synergistic, reinforcing developments that can potentially leave an adversary far behind. In the case of the PRC, and especially the PLA, the development of the PLA Strategic Support Force (PLASSF) may well be this kind of fundamental, devastating breakthrough.

The PLASSF brings together China's electronic warfare, network (including cyber) warfare, and space warfare forces. It is noteworthy that no other military has brought these kinds of capabilities into a single force. China has concentrated within a single service forces familiar with a variety of cutting edge technologies, from hacking to space warfare to advanced electronic operations. Not only is PLASSF therefore most likely to benefit from advances in Chinese technologies, but it is organized to develop suitable doctrines to exploit those same advances.
For the United States, then, the challenge from China is likely to be increasingly from a combination of both new technologies that China itself has developed, and old and new technologies organized and employed innovatively. An effective response cannot simply be focused on one or another technological development (although emerging and exponential technologies ***can*** be game-changers). Instead, it must involve both the U.S. government and the broader American society. It must include flexibility in our approach to organizations, roles, and missions, as well as openness to new technologies. Only in this manner can we effectively meet the Chinese challenge.

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