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Wilson China Fellowship

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Abstract

Technology competition is the fundamental driver of long-term US-China strategic competition. Technology racing will de ne the bilateral rivalry over the coming decades, and it is an innovation marathon that American policy makers must navigate to preserve the United States' security and economic competitiveness. A er taking power in 2012, Xi Jinping launched a determined campaign to shi the vital center of science and technology (S&T) from the United States to China by pioneering emerging technologies such as quantum. uantum technologies o er revolutionary potential to upend the geopolitical balance of power. Chinese champions are shi ing away from deep investments in quantum communication to keep pace with American progress in quantum computing and sensing. In the next decade, quantum technologies will enter a new stage of maturity that will have the potential to disrupt economies and security. ere is no certainty that the United States will retain its historic innovation leadership in quantum, nor that China will best the United States. e nation that best harmonizes its domestic innovation system will determine the course of the twenty- rst century's economic and security order.

Policy Implications and Key Takeaways

- US-China strategic technology competition will be determined by the country that best optimizes its innovation system. Two innovation systems are vying for global primacy, but it remains unclear which country will capitalize on technological revolutions unfolding today and in the future. e nation that integrates the products of its S&T ecosystem and private sector will retain leadership in the decades to come.

- China aims to close the gap on the United States' public and private advances in quantum computing and sensing. e race to utilize quantum has distinct rst mover advantages. Ingenuity, dedication, and luck could yield strategic surprise.

- Investing in human capital for science, technology, engineering, and math (STEM) will pay dividends for quantum and a range of other emerging technologies. US policy should address reforms for immigration and devoting resources to K-Ph.D. education that can build a heterogenous STEM talent pipeline.

- e United States possesses a well of quantum so power that China cannot replicate. An updated National uantum Strategy is essential for tailoring the right policy solutions for accelerating talent cultivation, public funding, research and development (R&D), and private capital.

Introduction

e United States and China are locked in an innovation race to control the technologies that will determine economic and security competitiveness in the twenty- rst century. Two con icting systems—the United States' public-private market approach and China's state-dominated economy—are searching for advantage. "Technological innovation has become the main battleground" for global leadership, Xi Jinping declared in 2021. Actions since his remarks are a testament to the centrality of technological competition between the United States and Cht cenw:3@4•ã£Hƒ!Ry •Z1 !%è BA3 ¥# ¢ ˆ. .ì

Xi is heeding lessons from the CCP's past to harness S&T for the state but to avoid Mao Zedong's tragedies that catalyzed an intellectual decay before Deng Xiaoping's modernization. A er the Second World War, Mao welcomed the repatriation of over 1,000 professors and graduate students across scienti c disciplines. Many, like Qian Xuesen, returned with a deep knowledge of ad vanced Western weapons. Mao's 1955 order to deliver an atomic-bomb galva

48 percent jump of new undergraduates between 1998 and 1999 ballooned further year-a er-year in the 2000s according to the National Bureau of Statistics of China.[3]

Chinese S&T earned respect in many elds, such as biotech, in the 2000s for tremendous progress, but questions lingered if the headway was sustainable. A 2010 assessment of China's S&T ecosystem outlined numerous factors con-straining China's optimistic plans to mature into a global S&T leader. Chinese R&D hubs failed to independently incubate the tools and talent to make signi cant strides. Imports constituted a critical source of R&D capital, machinery, and expertise. And although an authoritarian nation, national plans could not stem brain drain or fully capitalize on China's indigenous S&T resources. e CCP could not a ord to disrupt S&T cooperation with the United States.[4]

Chinese Vice Premier Wen Jiabao in a 2008 Science without innovating, authors in Harvard Business Review article opined that the CCP circumscribed China's innovation capacity. Xi upended this specious assertion. In 2013, he called for speedy reform of CAS and China's S&T management to elevate China's basic research to propel innovation. e CCP's 2016 Innovation-Driven Strategy bore the imprint of his resolve to move beyond rhetoric into results. e strategy inextricably merged innovation and China's development, noting that China "entered a new normal" where the old motors of development

velopmao r.5 63 4m2R72.5 (.6 (t0.1 (f C)3..3 (e)]Tl)10.8 (o 63 4m)9 Tm c8.3 (2R7 from Zhang Yuzhuo, an energy scientist and the China Association of Science and Technology (CAST) Party Branch Secretary. Zhang candidly elucidated the factors that prevented China from pioneering S&T advances, including what he called "American containment." But he was frank that "we lack major theoretical breakthroughs and leading original achievements."[9]

Xi's ambition to overtake the United States in S&T compelled Congress and the Biden administration to act. A 2020 American Academy of Arts & Sciences publication criticized decades of post-Cold War failure to spend on innovation in a searing report titled Perils of Complacency. By reducing government's primacy in funding R&D over decades—as well as lacking a vision for in uencing private sector innovation—the United States ceded ground to China. e response in Joseph Biden's administration included a ra of industrial policy spending for the In ation Reduction Act, the CHIPS and Science Act, and the Advanced Research Projects Agency for Health. e dynamics of a US-China technology race called for federal spending on R&D in the technologies that will shape the twenty- rst century. Spending was married to export controls to establish, in National Security Advisor Jake Sullivan's words, "a small yard and high fence."[10]

In 2023, Xi explicitly responded to export controls and the United States' industrial policy by centralizing authority for S&T under the CCP. He chaired a February Politburo Study Session on S&T where he lauded self-su ciency in basic research that preserves rst mover advantages in the era of "big science." In early March, the National People's Congress submitted formal reforms to China's science and technolnterprise amid pressure from the United States and its allies. Xi praised the reorganization that inserts stronger party control with less authority in the Ministry of Science and Technoly (MOST) and greater oversight in a newly formed Central Science and Technolommission (STC). Xi insisted that China's capacity to "fully implement the strateor invigorating China through science" demanded Party control. MOST survived but CSTC o t2 0 0cials are entrusted with managing "the construction of the national innovation system and the reform of the S&T system." National planning duties will also fall to CSTC o t2 0 0cials—bending China's S&T landscape to the Party's will. Xi understands the stakes of the competition, especially for quantum where he has insisted China's innovators lead the charge to best the United States.[11]

China's national quantum capacity and his proximity to CCP technocrats and politicians.[13]

e United States possesses signal advantages of a dynamic private sector R&D landscape, superlative universities, a decentralized S&T infrastructure, allies and mechanisms for technology transfer, and diverse funding sources. e United States possesses quantum so power that China cannot match. But no responsible analysis would declare the United States the inconvertible frontrunner. Ingenuity, dedication, and luck could trigger strategic surprise.

State of Public and Private Funding

Since the bipartisan 2018 National 18 Na6 Tm [(S)-0.h18 Narigtct8 3/LangA

State of the Private Sector

Several American companies occupy industry leader positions in the race to dominate quantum computing. IBM, Google, Microso , Amazon, and Intel top the list of United States-based companies. IonQ, uantinuum, Atom, Psi uantum, and nearly 350 startups exist in a thriving ecology. IBM is peerless in its investments in R&D, quantum cloud access, international partnerships, talent development, public outreach, and sales of quantum computers. No other corporation publishes a detailed roadmap that

A Basic Quantum Introduction for Policy Audiences

 uantum technologies use theories and discoveries from quantum mechanics for a range of use cases. Contemporary lasers, electron microscopes, atomic clocks, and magnetic resonance imaging (MRI) machines operate on principles of quantum physics. e di erence between today's tools and future quantum sensing or computing can be distilled to acute improvements in precision and speed. uantum is best divided into sensing, computing, and communications. ese three elds possess the latent potential for transforming a range of applications that will reshape security, economics, and everyday life. Preeminence in quantum carries distinct rst mover advantages for a diverse set of industries and nation-states. uantum computers will not replace a modern desktop or laptop computer, nor will civilians possess portable quantum sensors in the near term. uantum technologies will enable faster processing and utility for AI, cloud computing, communication networks, biomedical research and design, and myriad other elds.

 e fundamental data unit for quantum technologies is the quantum bit, known as a qubit. ere are many types of qubits, and each qubit possesses unique properties for diverse applications. Currently, the best funded quantum experiments use superconducting, t 2.3 (i)-2.1 (a)-9edimondse8 (,)-10 (t)-1

Google’s 762. Origin places sixth on the list with 234 and Baidu at eighth with 186. Other Chinese companies such as Tencent climbed from two patents in 2020 to ninety-three by 2022—evidence of several Chinese entities such as SpinQ surging into quantum computing patents. European companies, although behind the United States and China, are joining in the rising tenor of controlling intellectual property for quantum computing. Patents represent an imperfect snapshot of the quantum ecosystem, but they document Chinese companies’ climb that shows no signs of abating.[15]

Communications

uantum communication uses qubits to protect and transmit data. uantum communication via quantum networks can encode qubits for only two parties to decode the data, known as quantum key distribution (QKD). One approach entails data sent via particles of light known as photons, and this enables space-based quantum communications that joint Chinese-Austrian researchs seamonstrated qno2-10.9 (t0)3.2 (o1)4.9 (o6v)-15.3 (i)-2.1 (a p)-13.3

was launched at the Jiuquan Satellite Launch Center on August 16, 2016. Pan and a team of researchers experimented with transmitting data via photons within China between the Nanshan Telescope in Xinjiang and Xinglong Observatory in Yanshan. e UESS team confronted the obstacles that photon signals decay across distances, thus degrading QKD's reliability. UESS's team sustained photon signals between Xinjiang and Yanshan and other ground stations before initiating the next step of the collaboration with Zeilinger's team. e next and more signi cant stage tested a secure seventy- ve-minute video conference from UESS to the Austrian Academy of Sciences in 2017 via Micius. QKD secured the Beijing-Vienna call by trans mitting secure keys to decrypt in real-time.[18]

Scienti c, reputational, and political accolades followed Micius's success. Micius proved the possibility of encrypted quantum communications for a backbone of a space-based quantum internet. It also earned notoriety as the rst quantum experiment that captured the imagination and attention of today's global media, technologists, and rivals. Pan was named to *Time* magazine's Top 100 People—where Zeilinger praised his former student for advancing a quantum internet—and he won a ra of prestigious international scienti c awards.[18]

Did Micius test and prove QKD as a(n)19.6 (t 1(n)9.9 (c)-.w.38762 (a)-2.7 (o) with a photonic quantum computer named *Jiuzhang*. Similarly, a joint CAS- uantumCTek quantum chip named *Zuchongzhi-2* boosted its total qubits from sixty-six to 176 in 2023, with a new online platform that is open to researchers globally. Advances in quantum computing will enable cloud computing, like Alibaba's eleven qubit cloud, and the steady evolution of China's aim to control and secure information via quantum communications.[21]

Pan and other scientists in China maintain an active research agenda into 2023 for boosting QKD's delity, and they continue to achieve breakthroughs. Dual papers published in *Physical Review Letters* by teams led by Pan and a Chief Scientist at the Beijing Academy of uantum Information Sciences Zhiliang Yuan tested and substantiated QKD's transmission over 600 miles via optical bers without intermediary tools to repeat the signals. e separate tests gained e ciencies across distances and reliability of data transmission. Pan, Yuan, and others' published research is a testament to China's near monopoly of quantum communications peer reviewed publications and R&D for commercialization.[22]

e PLA aspires to operationalize quantum communications for strategic and tactical use. A 2011 MOST press release shared that the PLA deployed its rst quantum-encrypted communication tool. In 2014, an article in a PLA publication *China National Defense News* proclaimed quantum encryption's potential to ensure secure PLA communications for joint operations.[23] Several years later in 2018, a PLA post on WeChat publicized the military's use of a device with dimensions akin to an iPhone that functioned as a quantum encrypted terminal. e 2018 post touted that the terminal was integrated with Micius for space-terrestrial quantum communication. Although the PLA exhibited a sample terminal at the 2018 Ninth Military-Civilian Dual Use Technology Expo, the network had yet to graduate from testing to utility. PLA investment in quantum branched out from communications into sensing and training a generation of experts. In July 2022, the National University of Defense Technology opened a quantum research institute with focus areas of quantum communications—ranging from photon delity to potential the decades to come. Urgent policies are necessary to preserve the United States' short- and long-term innovation competitiveness for S&T as a whole and quantum technologies:

- Invest in People Immediately—America's immigration system for highly skilled individuals requires immediate overhaul and the United States suffers from the lack of a bold nation-wide push for STEM K-Ph.D. education. The United States' historic innovation excellence was partially owed to its ability to attract the best and brightest. Highly skilled immigrants must navigate a byzantine immigration process. Legislation to remedy this is key to recruit and retain the world's best and brightest—including Chinese nationals—for competing in quantum by developing a heterogenous STEM talent pipeline. Fixing immigration must be paired with enduring investments in America's STEM education to prepare US citizens for the technology revolutions ahead.

- Forge A New Innovation Consensus—The old balance of Washington taking a back seat as Silicon Valley set the nation's innovation trajectory is broken. Government once again must reassert its primacy in shaping innovation for national security. The Trump administration's Operation Warp Speed and the Biden administration's industrial policy and export controls point to the right direction of this rebalancing by leveraging federal spending to both shape incentives and cooperate with the private sector. The next few years are critical for cementing a new innovation consensus that benefits from historical lessons while also paving the way for an S&T ecosystem that delivers tangible gains for national security.

- Make Enduring S&T Investments—Government is the only national institution that can ensure guaranteed funding for frontier, risky S&T that is a critical enabler for the United States' competitiveness. For instance, preeminence in quantum technologies, as with other critical emerging technologies, can only thrive with sustained federal funding. The Departments of Energy and Defense will play a key role in nurturing S&T fields that the private sector cannot fund. Lower technology readiness levels fall outside industry's risk profile, and government must fill the gap to maintain the path for the private sector to deliver products to market.

- Update the National Quantum Strategy—Since the first and only National Strategic Overview for Quantum in 2018, the field has grown by leaps and bounds, US-China competition is amplifying, and, most importantly, technology readiness level timelines are compressing. The intersection of science and geopolitics requires that White House convene experts from industry, academia, and government to publish a new guide for national planning. The report can appraise progress of the National Quantum Initiative, identify shortcomings, and propose

Notes

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