At this time of disruptive transitions, the new U.S. National Defense Strategy rightly recognizes that the character of warfare is changing due to the advent of a range of disruptive technologies.\[1,2\] In particular, the strategy highlights rapid advances in advanced computing, big data analytics, artificial intelligence (AI), autonomy, robotics, directed energy, hypersonics, and biotechnology, which are characterized as “the very technologies that ensure we will be able to fight and win the wars of the future.”\[3\] The emergence of and unique convergences among these technologies could transform current paradigms of military power in uncertain, unpredictable ways. In addition, since commercial developments have been a primary driver of recent progress in many of these disparate technologies, the diffusion of advances will occur much more quickly and prove difficult to constrain, especially with the free exchange of ideas and talent across borders. In recent history, military-technical advantage has been a key pillar of U.S. military predominance. However,
today's trends, including China's rapid emergence as a scientific powerhouse, seem unlikely to allow for the U.S. or perhaps any actor to achieve uncontested edge, and poor policy choices could lead to disadvantage.

THE FUTURE OF U.S. MILITARY COMPETITIVENESS WILL DEPEND UPON THE ABILITY TO REMAIN A LEADER IN INNOVATION IN THESE CRITICAL TECHNOLOGIES THROUGH A NATIONAL SURGE IN SCIENCE, WHILE ALSO BUILDING UPON PERHAPS MORE ENDURING ADVANTAGES IN TALENT AND TRAINING TO ADVANCE INNOVATION IN CONCEPTS OF OPERATIONS.

As the U.S. starts to prioritize long-term strategic competition with China and Russia, military innovation is emerging as a new frontier for great power rivalry. The National Defense Strategy is striking in its characterization of China as a revisionist power whose military modernization agenda seeks "Indo-Pacific regional hegemony in the near-term and displacement of the United States to achieve global preeminence in the future."[4] This could be the start of a historic shift in U.S. strategic orientation, in response to a historic challenge. The future of U.S. military competitiveness will depend upon the ability to remain a leader in innovation in these critical technologies through a national surge in science, while also building upon perhaps more enduring advantages in talent and training to advance innovation in concepts of operations.

It is notable that China has emerged as a technological powerhouse with ambitions to take the lead in each of the emerging technologies highlighted in the National Defense Strategy. China has achieved dominance in supercomputing with the world's top two fastest supercomputers, the Sunway TaihuLight and the Tianhe-2.[5] Concurrently, China is pursuing a national big data strategy pursuant to its focus on building a dynamic digital economy as well as for defense purposes.[6] As artificial intelligence has emerged as a priority at the highest levels, China is advancing an all-of-nation strategy to advance next-generation AI development for commercial and military applications, seeking to emerge as the world's "premier AI innovation center" by 2030.[7] While actively pursuing military robotics, Chinese research and development is also enabling higher levels of autonomy in unmanned (i.e., uninhabited) systems.[8,9] The Chinese defense industry is progressing in the development of directed energy weapons, including lasers, railguns, and high-power microwave weapons.[10] The Chinese People's Liberation Army (PLA) has invested in hypersonic flight vehicles and scramjet engines, recently testing the DF-17, a ballistic missile equipped with a hypersonic flight vehicle.[11,12] Concurrently, China has invested billions in biotechnology and genomics with a focus on precision medicine.[13] Although the U.S. National Defense Strategy does not explicitly include quantum science, it is also clear that China aspires to
lead in quantum technologies that could have transformative implications, emerging as a world leader in quantum cryptography and communications, catching up in the race for quantum computing, and progressing in quantum metrology and sensing.[14]

China’s trajectory and ambitions to become a true “science and technology superpower” (科技强国)—have been advanced through a state-driven model of innovation.[15] This agenda to transform into a “nation of innovation” involves long-term planning targeted to strategic objectives with high levels of funding and investments for research and development, along with attempts to foster a more dynamic startup ecosystem.[16] In the tradition of Chinese “technonationalism”—and history of successful ‘moonshot projects’ like “Two Bombs, One Satellite”—such efforts are resource intensive, often involving ambitions mega-projects that devote tens or even hundreds of billions of dollars in funding, and can leverage tech transfer to advance indigenous innovation.[17] To date, licit and illicit forms of tech transfer have been major enablers of China’s military modernization.[18] However, Chinese Communist Party and PLA leaders aspire to advance not merely indigenous but truly disruptive innovation to pioneer new breakthroughs, particularly in emerging technologies.[19] According to a recent National Science Board report, China is already second only to the U.S. in research and development spending with 21% of the world’s total as of 2015, and, with 18% annual growth in funding, is on track to surpass the U.S.[20] There are also robust indicators of increases in both the quantity and the quality of China’s scientific research.[21]

As of 2018, China has overtaken the U.S. as the world’s largest producer of scientific articles. [22] Of note, in 2017, Chinese artificial intelligence startup Malong Technologies won the inaugural WebVision contest, which tested computer vision driven by artificial intelligence, and Yitu Tech, a Chinese facial recognition startup took first place in the Facial Recognition Prize Challenge hosted by the Intelligence Advanced Projects Agency.[23,24] Meanwhile, China’s biotech industry is flourishing, supported by an estimated $100 billion in investment in the life science, and Chinese scientists have conducted the most human trials involving CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats), which is used as the basis for gene editing.[25,26] The new National Laboratory for
Quantum Information Science will become the world’s largest quantum research facility, with over $1 billion in funding to pursue advances in quantum computing and reportedly engage in research on other quantum technologies that may be of immediate use to China’s armed forces.\textsuperscript{[27]} Indeed, although these technologies do, of course, have a range of impactful commercial applications, advances will also likely be turned to defense applications.

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Comparison of different technology hubs, as published in "CES becomes the Chinese electronics show as Shenzhen, Dongguan exhibitors throng fair (http://www.scmp.com/tech/china-tech/article/2127518/ces-becomes-chinese-electronics-show-shenzhen-dongguan-exhibitors)," South China Morning Post, January 9, 2018.

As China undertakes an ambitious military modernization agenda, its model of defense innovation is characterized by the pursuit of a national strategy of “military-civil fusion” (军民融合) that seeks to leverage synergies between academic, industry, and military advances, particularly in emerging, inherently dual-use technologies.\textsuperscript{[28,29]} As Chinese enterprises become major engines for innovation, the state is seeking to harness their dynamism as national champions.\textsuperscript{[30]} Increasingly, the notion of military-civil fusion is becoming more of a reality as a result of the top-level focus on its advancement, which is directed by the Chinese Communist Party’s Military-Civil Fusion Development Commission (中央军民融合发展委员会).\textsuperscript{[31]} Established in early 2017 under the leadership of Xi Jinping himself, this commission is pursuing a series of plans that seek to break down traditional barriers between commercial and defense enterprises.\textsuperscript{[32,33]} For instance, Tsinghua University has established the Military-Civil Fusion National Defense Peak Technologies Laboratory (清华大学军民融合国防尖端技术实验室), which will create a platform for the pursuit of dual-use applications of emerging technologies, including artificial intelligence.\textsuperscript{[34]} Beijing’s Zhongguancun National Innovation Demonstration Zone—which has, by some metrics, replaced Silicon Valley as the world’s top tech hub—is also engaged in this military-civil fusion agenda.\textsuperscript{[35,36]} This structural approach could potentially advantage PLA efforts to ensure that commercial advances can be readily, and perhaps rapidly, transferred for military employment.

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**PERHAPS IRONICALLY, CHINA’S CURRENT WHOLE-OF-NATION APPROACH TO SCIENTIFIC ADVANCEMENT HAS SOME PARALLELS TO AND HAS BEEN, IN PART, INSPIRED BY U.S. EFFORTS DURING THE COLD WAR, AFTER THE SOVIET UNION’S LAUNCH OF SPUTNIK CATALYZED THE SPACE RACE.**

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<table>
<thead>
<tr>
<th>Silicon Valley</th>
<th>Beijing</th>
<th>Shanghai</th>
<th>Shenzhen</th>
<th>Hangzhou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical area</td>
<td>4,801.8 km(^2) (Zhongguancun National Innovation Demonstration Zone)</td>
<td>458 km(^2)</td>
<td>296.4 km(^2) (Zhejiang National Innovation Demonstration Zone)</td>
<td>397 km(^2) (Shenzhen National Innovation Demonstration Zone)</td>
</tr>
<tr>
<td>Monthly average tech salary (in 2015)</td>
<td>US$9,953</td>
<td>9,420.14 yuan (US$1,414.41)</td>
<td>9,057.76 yuan (US$1,367)</td>
<td>9,071.29 yuan (US$1,362)</td>
</tr>
<tr>
<td>Notable companies</td>
<td>Alphabet, Apple, Facebook</td>
<td>Baidu, JD.com, Xiaomi, Didi Chuxing</td>
<td>Lu.com, Zhong An Online Property and Casualty Insurance, Ele.me</td>
<td>Tencent Holdings, Huawei Technologies, Didi</td>
</tr>
<tr>
<td>GDP</td>
<td>US$223 billion</td>
<td>2.49 trillion yuan (US$375.2 billion)</td>
<td>2.75 trillion yuan (US$413.7 billion)</td>
<td>1.95 trillion yuan (US$290.6 billion)</td>
</tr>
<tr>
<td>Population</td>
<td>3.05 million</td>
<td>21.7 million</td>
<td>24.15 million</td>
<td>11.38 million</td>
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</table>
By contrast, the current U.S. model for innovation has looked to the private sector as the engine of innovation for science and in defense. Certainly, it is true that U.S. enterprises remain global leaders in most critical scientific domains, and U.S. tech companies spend seemingly stratospheric amounts on research and development. For instance, in the past fiscal year, Amazon spent $16.1 billion, Alphabet $13.9 billion, and Intel $12 billion.[37] Nonetheless, major U.S. companies are seemingly starting to devote less to basic and applied research than many have historically, focusing instead on later stages of development that are more likely to be lucrative.[38] Given these trends, it is important to raise the question as to whether private funding and investments may not be enough to enable long-term dynamism and national competitiveness in innovation, relative to the pace at which it is occurring in China.

Inherently, even when massive amounts of commercial investment is occurring, there can be a lack of adequate support for high-risk, early-stage research that is less likely to have viable commercial applications in the near term. Traditionally, government funding for research and development has been vital to bridge this gap.[39] However, there are reasons for serious concern that declining spending in federal outlays for basic research, exacerbated by budget cuts and inconsistencies in funding, could result in an innovation deficit that could seriously undermine long-term U.S. competitiveness.[40] So too, the persistent shortcomings in U.S. primary science education are troubling, as human talent remains critical strategic resource in enabling innovation. Perhaps ironically, China’s current whole-of-nation approach to scientific advancement has some parallels to and has been, in part, inspired by U.S. efforts during the Cold War, after the Soviet Union’s launch of Sputnik catalyzed the Space Race. At the time, the U.S. response encompassed not only rapid
increases in federal funding but also a greater recognition of the strategic importance of science education at all levels.[41] That focus on taking advantage of all available talent resulted in the inclusion of those often underrepresented in science and defense, from women cryptographers to African-American mathematicians, who are only belatedly starting to receive the credit deserved for their historic contributions.[42] Today, however, as the U.S. government’s involvement in driving innovation has diminished, the Department of Defense is looking to Silicon Valley for next-generation technologies. In the process, the challenges of overcoming what has been characterized as a rocky relationship can act as an impediment to the deeper integration of commercial and defense technological development that has occurred within the U.S. historically and is starting to progress today in China.[43]

**IN RECENT HISTORY, THE U.S. HAS BEEN THE WORLD LEADER IN INNOVATION, BUT INNOVATION IS NOT AN AMERICAN BIRTHRIGHT.**

What do these divergences in current U.S. and Chinese models of technological and defense innovation mean for the future strategic balance? At a time when the new National Defense Strategy recognizes long-term strategic competition with China and Russia as principle priorities for the U.S, it is clear the future of U.S. economic dynamism and military power may depend upon the U.S. ability to remain a leader in this new wave of innovation.[44] Given China’s trajectory and ambitions in innovation, the U.S. military must also recognize the PLA’s potential emergence as a true peer competitor and reevaluate the nature of U.S.-China military and technological competition accordingly. Within this competition, the new National Security and Defense Strategies highlight that it is vital to protect the “National Security Innovation Base,” which is defined as “the American network of knowledge, capabilities, and people—including academia, National Laboratories, and the private sector—that turns ideas into innovations.”[45] Certainly, taking action to mitigate illicit technology transfers, including through cyber espionage, should be an important component of a strategy to ensure U.S. innovation advantage. However, the vitality of the U.S. innovation base will require a more ambitious, far-reaching strategy.

The U.S. must undertake a surge in science to ensure enduring competitive advantage. Such a surge should start by targeting strategic investments to long-term research and development and should also concentrate on educating and attracting top talent. For well over a decade, concerns about American competitiveness in science and technology have been growing, but without a forceful or decisive response.[46] So too, within the defense industry, after years of declining budgets, the severe market shock resulting from sequestration and budget caps have undermined the U.S. defense industry, reducing the number of vendors and chilling research and development.[47] In recent history, the U.S. has been the world leader in...
innovation, but innovation is not an American birthright. Rather, it is perhaps the result of unique circumstances that has created an unparalleled innovation ecosystem, in which our highly vaunted private sector has been only one of the protagonists. To chart a path forward, U.S. leaders might look to the history of successful past partnerships among the U.S. government, universities, and enterprises, whether in World War II, the Space Race, or even the War on Cancer. At the same time, U.S. leaders must remember that this is not the Cold War, but rather a highly complex, globalized, and interconnected era in which the U.S.-China relationship is multi-faceted and complicated. For the U.S. to continue to lead in science and technology will require ensuring the continued leverage of its greatest competitive advantages: the vitality and openness of its innovation ecosystem, which has allowed the U.S. to attract talent from throughout the world.

**ULTIMATELY, THE FUTURE OF WARFARE REMAINS UNCERTAIN BUT WILL BE DETERMINED BY TODAY’S STRATEGIC CHOICES.**

However, it is also critical to recognize—given the potential for the rapid diffusion of key technologies and China’s rise as a would-be superpower in science and technology—that it may not be feasible for the U.S. to regain or retain uncontested technological advantage. Consequently, U.S. military advantage might be best assured through leveraging perhaps more enduring advances in the human and organizational dimensions of innovation in which the Chinese military may struggle, including through creating new concepts of operations and perhaps even new organizational structures. Ultimately, the future of warfare remains uncertain but will be determined by today’s strategic choices.

Elsa B. Kania is a Featured Contributor on The Strategy Bridge and an Adjunct Fellow with the Technology and National Security Program at the Center for a New American Security, where she focuses on Chinese defense innovation and emerging technologies. She is the author of “Battlefield Singularity: Artificial Intelligence, Military Revolution, and China’s Future Military Power.”

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(submissions@thestrategybridge.org)
NOTES:

[1] The notion of disruptive transitions was a major focus of the 2018 Raisina Dialogue, which I appreciated having the chance to attend: www.orfonline.org/raisina-dialogue/


