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China's Threat to American Government and Private Sector Research and Innovation Leadership

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Chairman Nunes, Ranking Member Schiff, distinguished members of the committee, thank you for the opportunity to discuss the challenge that China poses to American research and innovation leadership.

In my remarks, I will discuss the near-term threat of China's attempts to exploit the U.S. innovation ecosystem and also address the long-term challenge of China's advances and ambitions in strategic technologies.

In recent history, U.S. leadership in innovation has been a vital pillar of our power and predominance. Today, however, in this new era of strategic competition, the U.S. confronts a unique, perhaps unprecedented challenge to this primacy.

Given China's continued exploitation of the openness of the U.S. innovation ecosystem, from Silicon Valley to our nation's leading universities, it is imperative to pursue targeted countermeasures against practices that are illegal or, at best, problematic.

At the same time, our justified concerns about constraining the transfer of sensitive and strategic technologies to China must not distract our attention from the long-term, fundamental challenge—to enhance U.S. competitiveness, at a time when China is starting to become a true powerhouse and would-be superpower in science and technology (科技强国).

China's Quest for Indigenous Innovation

China's attempts to advance indigenous innovation (自主创新) have often leveraged and been accelerated by tech transfer that is undertaken through both licit and illicit means. This history and these techniques of industrial espionage have been extensively documented, and cases abound.[1] Some of the more notorious examples include the theft of data on the F-35[2] and recent Chinese targeting of the semiconductor industry, which has involved targeted poaching of engineers and the theft of intellectual property,[3, 4] as well as attempted and successful acquisitions.[5]

At the same time, there have been well-funded and significant initiatives within China to build up indigenous technology and innovation resources. Even fairly recently, it would not have been inaccurate to say that Chinese "indigenous" innovation seemed to be an oxymoron, due to this heavy reliance upon foreign technologies. However, it would be arrogant, even dangerous, to claim today that China "can't innovate," when there is such abundant evidence to the contrary.

Beyond the hype and fear, China's ambitions of technological dominance should be taken skeptically, but seriously. In particular, the Chinese government has launched sixteen S&T "megaprojects,"[a] increased funding for basic research,[b] and prioritized the education and recruitment of talent.[6, 7] China aspires and has the potential to emerge as a leader in new frontiers of innovation, including artificial intelligence and quantum technologies.

Artificial Intelligence:

Although its ambitions to "lead the world" in AI may seem grandiose, China could emerge as a true 'AI superpower."[8] By all available indicators, from patents to publications and investments, China is already emerging as a global center of AI innovation.[c] As early as 2013, China's AI publications overtook those of the U.S. to become the world's most cited papers.[9, 10] As of 2017, China produced 27.7% of the academic research on AI published in the world. Chinese companies also appear to be overtaking their U.S. competitors and counterparts in AI-related patent applications, including in deep learning.[11] Beyond billions in state funding,[d] China is also attracting a sizable and increasing proportion of global investment in AI, which amounted to $27 billion in 2017, constituting 60% of the world total across the past five years.[12, 13] In 2017, Chinese AI start-ups received nearly 50% of global funding to start-ups, surpassing the U.S.[14]

The Chinese government has prioritized AI at the highest levels and is dedicating strong state support to its advancement. The New Generation AI Development Plan (新一代人工智能发展规划) characterized this strategic technology as a "new focal point of international competition," declaring China's intention to emerge as the world's "premier AI innovation center" by 2030.[15] The Three-Year Action Plan to Promote the Development of New-Generation AI Industry (促进新一代人工智能产业发展三年行动计划) (2018–2020) called for China to "establish international competitive advantage" in AI products by 2020.[16] China's central and many local governments are

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[a] These include: aero-engines and gas turbines, deep-space and deep-sea exploration, quantum communications and computing, brain-science and brain-inspired research, national cyberspace security, integrated space-to-earth information networks, big data, smart manufacturing and robotics, and new key materials development. In addition, artificial intelligence was added as another megaproject as of July 2017.

[b] China's funding for R&D in basic sciences doubled in the past five years, from 41.2 billion RMB (about $6.5 billion U.S. dollars) in 2011 to 82.3 billion RMB (about $12.25 billion) in 2016, according to China's Ministry of Science and Technology.

[c] At the same time, it is important to recognize that China is not "winning" in AI *per se*, and the frequent characterization of advances in these technologies as a race is not particularly accurate or constructive at this point.

[d] Despite frequent claims to the contrary, the Chinese government has not committed to spending $150 billion on AI. It is difficult to come up with a precise estimate of current levels of funding, across both central and local governments, which would include a number of guidance funds, science and technology plans, and institutions like the National Natural Science Foundation of China.

providing high and ever-rising levels of funding for the research, development, and commercialization of AI applications and next-generation technologies. For instance, the city of Tianjin alone has created a new $16 billion fund for AI.[17] At the same time, China's policies seek to create a robust foundation for innovation through developing standards and regulatory frameworks and supporting the availability of data, testing, and cloud platforms.[18, 19]

If there is a U.S.-China "AI arms race" today, then the primary battlefield is talent.[e, 20] Confronting major shortfalls in AI talent relative to the intense demands, the Chinese government is aggressively advancing a range of training and educational initiatives.[21] As of late 2017, China had an estimated 18,232 AI talents, or a mere 8.9% of the world's total, by one estimate, ranking behind the U.S.,[f] which is estimated to account for 13.9% of the world's AI talent.[22] According to data from LinkedIn,[23] of the approximately 1.9 million AI engineers worldwide, nearly one million reside in the US, while just about 50,000 are in China.[24] In response to this gap, China's Ministry of Education released a plan to build up AI as a discipline in Chinese higher educational institutions,[25] including through establishing new AI academic and research institutes at universities throughout China.[26] Of note, Kai-Fu Lee's Sinovation Ventures has partnered with the Ministry of Education and Peking University to launch a new program that plans to train at least 500 AI teachers and 5000 AI students in top universities in five years.[27] At the same time, Chinese state talent plans continue to concentrate on recruitment.[28] China may lag behind the U.S. in talent for now, but it is committed to developing the requisite human resources.

China's 'national champions' – Baidu, Alibaba, Tencent, and iFlytek – are global leaders in AI that also benefit from strong state support, while contributing to national priorities for AI development. For instance, Baidu is leading China's National Engineering Laboratory for Deep Learning Technologies and Applications (深度学习技术及应用国家工程实验室),[29] and iFlytek, which makes 'China's Siri,' is leading the State Key Laboratory of Cognitive Intelligence (认知智能国家重点实验室).[30] At the same time, these players are heavily investing in research and development, while undertaking investments and acquisitions within China and worldwide. For instance, Baidu's R&D budget in 2017 was about $2 billion,[31] and Alibaba plans to invest $15 billion into disruptive technologies, including artificial intelligence and quantum technologies, through its new DAMO (Discovery, Adventure, Momentum, and Outlook) Academy.[32] These champions will also undertake the development of new open innovation platforms in AI: Baidu will be responsible for autonomous vehicles, Alibaba Cloud (Aliyun) for smart cities, Tencent for medical imaging and iFlytek for smart voice technologies.[33] The platforms will be piloted in the Xiong'an New Area, a development southwest of Beijing that is intended to be a futuristic demonstration of Chinese innovation and to showcase AI technologies and applications in action.[34] In addition, to advance China's national strategy of military-civil fusion (军民融合),[35] Baidu is partnering with the China Electronics Technology Group (CETC), a state-owned defense conglomerate, through the Joint Laboratory for Intelligent Command and Control Technologies (智能指挥控制技术联合实验室), to pursue applications of big data, cloud computing, and artificial intelligence, in military command and

[e] Please note that I do not think that "arms race" is an apt framing for U.S.-China military and strategic competition in AI for a variety of reasons, including that "AI" is not a weapon but rather a diverse range of technologies for which development is driven predominantly by commercial enterprises.
[f] It is worth noting that estimates of AI talent vary greatly across different measurements, depending on the methodology used to count, the requirements for who is counted, etc.

information systems.[36] Beyond these champions, a diverse and extensive ecosystem of AI start-ups is emerging. As of May 2018, there are an estimated 4,040 AI enterprises in China, of which 1,070 of those companies are in Beijing alone.[37, 38]

Quantum Technologies:

China aspires to lead in quantum science and to pioneer the development of a range of quantum technologies that could prove transformative. Chinese scientists have launched the world's first quantum satellite, broken world records in quantum computing,[39] and even claimed to achieve rapid progress in the development of quantum radar.[40] The Chinese government has launched a national megaproject in quantum communications and computing, prioritizing these technologies for advances by 2030.[41] Building upon a history of steady support for basic research and development, China's quantum innovation ecosystem is dynamic and characterized by integration between academia, industry, and the military. China is in the process of constructing a National Laboratory for Quantum Information Science (量子信息科学国家实验室),[42, 43] which has received 7 billion RMB ($1.06 billion) in funding to start.[g, 44] This new national laboratory will pursue advances in quantum technologies, including computing, while reportedly engaging in research "of immediate use" to the Chinese military.[45] Meanwhile, Alibaba has partnered with the Chinese Academy of Sciences to establish its new Quantum Computing Laboratory,[46] and Baidu has also recently established an Institute of Quantum Computing.[47] Although China has not emerged as a clear leader quantum computing, Chinese researchers may catch up and surpass their competitors in the decades-long marathon to develop a fully functional quantum computer. At the same time, the Chinese defense industry is actively engaged in the development of quantum radar, imaging, and navigation technologies that could have more direct and immediate military applications.

China's Tactics for Tech Transfer

Despite such estimable progress in innovation, it is critical to recognize that also China continues to confront considerable challenges, including a lack of talent and core technologies.[h] These obstacles motivate the "going out" (走出去) of Chinese enterprises and their attempts to facilitate the "bringing in" (引进来) of tech and talent back to China.[48] Although China is seeking to progress beyond reliance on tech transfer to engage in truly original innovation, state-driven attempts to leverage foreign innovation ecosystems will likely remain quite prevalent, in the U.S. and worldwide, for the foreseeable future. These efforts constitute a complex and often opaque landscape of activities, and this testimony does not attempt to be comprehensive in its coverage of them. For instance, it is clear that, despite the 2015 Xi-Obama agreement, Chinese cyber espionage, including that undertaken for purposes of IP theft, has continued,[49] as in the recent troubling compromise of a Navy contractor by hackers from the Ministry of State Security.[50] Beyond such illicit tactics, I seek to

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[g] Although news reports misreported this as $10 billion at the time (and continue to do so), there is no evidence in the available sources that there are plans to spend that much on this particular laboratory at this time, though total levels of funding may very well amount to tens of billions in total in the years to come. For instance, In addition, the new Anhui Quantum Science Industry Development Fund, created in December 2017, also plans to devote 10 billion RMB (nearly $1.6 billion) in funding to quantum computing, communications, and metrology.

[h] China's level of advancement in science and technology is highly varied across and even within domains. For instance, China may lead in certain AI techniques and applications, such as facial recognition in particular, but is not yet considered a clear leader in all aspects of the discipline.

highlight a series of relevant examples of tactics and dynamics of tech transfer that will merit further consideration going forward. My remarks will concentrate on Chinese investments, incubators, and acquisitions focused on strategic technologies; the targeting and exploitation of U.S. academia and universities; and questionable research and commercial collaborations.

Investments, Incubators, and Acquisitions:

Chinese investments, as well as tech incubators and targeted acquisitions, can enable access to U.S. technologies that conveys a level of risk, but also opportunities for U.S. companies as well.[51] In many respects, the extensive engagement and collaboration in innovation between the U.S. and China, often characterized by open exchanges of ideas, talent, and technologies, can be mutually beneficial in enriching and accelerating innovation in both countries.[52] However, to the extent that the Chinese government seeks to direct and exploit these efforts with levels of involvement that are often opaque or obscured, it is worth reevaluating the risks and benefits of these 'entanglements.'

For instance, the dramatic increase in levels of Chinese investment in strategic technologies within the past several years reflects the confluence of state priorities and commercial enthusiasm that can be very difficult to differentiate in practice. Between 2012 and mid-2017, China-based investors engaged in tech investments of $19 billion in the U.S., across 641 deals, focusing on AI, robotics, and augmented or virtual reality, according to data from CB Insights.[53] Not all Chinese investments are risky or problematic – particularly if there are safeguards to limit access to IP in place – and this influx of capital can also be beneficial to U.S. start-ups that may otherwise struggle to receive adequate funding.[54] However, the access and insights that investment can enable, including when an investor takes on a board position in the company, can enhance situation awareness in ways that might inform future targeting and acquisitions of sensitive technologies.

These trends and dynamics in Chinese investments will merit much more extensive analysis and consideration, given the scope, scale, and variety of these activities. Although the majority of Chinese venture capital investment in the U.S. is assessed to be private and primarily financially-motivated, certain investments can be linked to or directed by state priorities in ways that are not necessarily transparent.[55] As scrutiny of Chinese investments in Silicon Valley increases, pursuant to proposed updates to CFIUS, certain investors and venture capital funds will look to obscure further the origins of their funding and their connections to China or the Chinese government in ways that may render balanced evaluation of risk even more challenging. Certain funds are directly guided and supported by the central or local governments or elements of China's defense science and technology ecosystem, such that their engagements with U.S. start-ups may serve to draw their tech and talent back into it. While a full review of relevant investors would be beyond the scope of this testimony, several examples serve to illustrate the focus and nature of these activities.

- The China Investment Corporation, China's national sovereign wealth fund, has sought to pursue greater access and investments in the United States,[56] including in Silicon Valley, where it invested in Unity Technologies, a platform for virtual/augmented reality.[57]

- Danhua Capital (丹华基金, DHVC)[i] was established in 2013 in Silicon Valley by the Zhongguancun (ZGC) Development Group (中关村发展集团),[58] which is a state-owned enterprise of the Beijing municipal government.[59]
    - ✧ DHVC, which manages total investments of $600 million as of fall 2017,[60] has made 137 investments in total as of July 2018, with a focus on emerging and disruptive technologies, including Meta, a leading company in augmented reality.[61]
    - ✧ DHVC affiliates have taken on board-related and/or advisory positions on a number of start-ups after investment.[62]
    - ✧ According to its co-founder, the fund is committed to "narrowing the gap" in technological development between China and the U.S.[63]
- HEDA Ventures, established and supported by the Hangzhou government's Economic and Technology Development Zone,[64] has invested in disruptive innovations, including in the biotech sector, such as Paragon Genomics.[65]
    - ✧ This fund received $150 million in total to start, and its objectives include to encourage overseas talents to settle in Hangzhou and to support the upgrading and transformation of China's domestic industries.[66]
- Qihoo 360, China's leading cyber security company, which is closely linked to the Chinese military and government,[67] has established a venture capital fund in Silicon Valley in order to support start-ups that it considers strategically significant.[68]
    - ✧ In addition, Zhou Hongyi, Qihoo's CEO and co-founder, serves as an advisor to 11.2 Capital, an early stage venture capital fund that has invested in "breakthrough" technologies, such as AI, AR/VR, robotics, and biotechnology, across a range of companies, including Ginkgo Bioworks.[69, 70]

To access talent, a number of leading Chinese tech companies, including Baidu, Alibaba, Tencent, Huawei, and iFlytek, have created or plan to establish one or more centers for research and development in the U.S.,[71] just as a number of U.S. companies, including recently Google, have created similar centers in China.[j] For U.S. and Chinese companies alike, this access to talent is advantageous to their innovation and competitiveness. When enterprises that have clear or direct links to the Chinese military or defense industry seek to establish such R&D centers or operations in the U.S. or worldwide, then that presence may raise greater concerns. For instance, CETC Software Information Services Co., Ltd. (中电科软件信息服务有限公司), a subsidiary of the China Electronics Technology Group Corporation (CETC), a state-owned defense conglomerate, reportedly established an innovation center in Silicon Valley in 2014,[k, 72] which seeks to take advantage of that ecosystem with a focus on big data and other advanced information technologies.[73]

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[i] Danhua Capital's full name is the "Zhongguancun-Stanford Emerging Technologies Venture Capital Fund" (中关村斯坦福新兴技术创业投资基金).

[j] For this reason, I would discourage considering policy options that restrict these commercial activities, lest U.S. companies become constrained in their own overseas R&D activities.

[k] Please note that I have not been able to find detailed accounts of its activities in Silicon Valley based on an initial search, which could imply that its presence and activities are fairly limited at present.

Beyond investments, China's presence in U.S. innovation ecosystems extends to include incubators and accelerators, of which there are at least eleven in total in Silicon Valley, that may enable more direct access to talent and technology than investment alone would typically provide.[74] For this reason, the risk and impact of these institutions, which may also often benefit U.S. start-ups through providing them support and access to China's market, merit further scrutiny.[l] Since their establishment is typically motivated by and characterized in terms of the benefits of access to U.S. talent, research, and technologies, these activities should be viewed in the broader context of Chinese efforts to leverage tech transfer though legal means that may, in some cases, prove problematic nonetheless to advance indigenous innovation.

- The ZGC Innovation Center in Silicon Valley (中关村硅谷创新中心) was established in May 2016 as an incubator by Zhongguancun (ZGC) Capital.[75, 76]
  - It has invested in major funds in Silicon Valley, such as Danhua (see above), Plug & Play, and KiloAngel,[m] while also leveraging an incubator that supports early-state U.S. start-ups, including through providing office space, financing, and business development.
  - According to its website, to incubate and 'accelerate' start-ups, it also helps facilitate these start-ups' pursuit of opportunities cooperation, mergers and acquisitions, etc. with major Chinese companies and arranges for them to go to China on field trips and roadshows.[77]
- The Hangzhou Silicon Valley Incubator (杭州硅谷孵化器), established in 2014 with support from the government of Hangzhou,[78] had, as of fall 2017, reportedly attracted 47 'overseas high-tech enterprises' to settle in Hangzhou.[79]
  - The projects that it has incubated have included companies in big data, cloud computing, and biotechnology, and the objective is to build a "bridge" for tech and talents to return to Hangzhou.[80]
- Lab36, an incubator founded in October 2014 and supported by Qihoo 360, has focused on the development of intelligent hardware, providing seed investment and partnerships to start-ups.[81]

Such activities extend well beyond Silicon Valley to other dynamic American innovation ecosystems, including to Boston's biotech sector,[n] which has attracted a number of Chinese biotech and pharmaceutical companies to establish R&D operations and incubators to access local talent.[82] In the Boston area, several incubators that involve partnership between the Chinese and the Massachusetts government may positively contribute to competitiveness but should also recognized as linked to China's strategic approach focused on the 'bringing in' of innovation resources back to China's domestic innovation ecosystems, many of which aspire to become "China's Silicon Valley."

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[l] To clarify, I mention these centers and incubators only as examples of activities that may merit further consideration in the context of current debates over risks of tech transfers, not to imply that there is any direct evidence that I have seen so far of wrongdoing. I caveat my concerns based on the fact that my research is limited to open sources available online, and I have not had the opportunity to visit or engage directly with these institutions. Moreover, since their establishment is relatively recent, it is likely that their impact has been fairly limited to date, though that may change as this focus on incubators, overseas innovation centers, etc. expands.

[m] In addition, its 'cooperative institutions' include Peakview Capital, C.M. Capital Foundation, Danhua Capital, and AngelList.

[n] The question of Chinese investments in Boston's biotech sector was not a topic that I had a chance to explore at length within the framework of this testimony but should receive further attention.

- The China-US Boston Innovation Center (CUBIC), founded in February 2015 with the backing of China's Ministry of Science and Technology, is located on the campus of MIT in the Boston Cambridge Innovation Center.[83] CUBIC is intended to become a platform for collaboration, including for mergers and acquisitions, between the U.S. and China.[84]
    - It focuses on helping U.S. enterprises enter the China market, including facilitating access to government resources, with the aim of seeking out top talent and technologies.[85]
    - CUBIC and its Miti Venture (米天创投) announced, with Chinese government officials in attendance, a strategic partnership that involved two new funds to incubate "outstanding overseas entrepreneurial teams."[86]
- The Shanghai Zhangjiang Boston Enterprise Park (上海张江波士顿企业园) was established in Marlborough, Massachusetts in February 2016, with support from the state government, under the guidance of the Shanghai government, with plans to construct innovation centers focused on biomedical technology, artificial intelligence, and semiconductor integrated circuitry, among others.[87, 88]
    - At the time, the president of China's National Eastern Tech Transfer Center (国家技术转移东部中心) highlighted this as an important "icebreaker," as the first case of U.S.-China cooperation in building a high-tech park, in ways that can help Shanghai to emerge as a global tech transfer hub.[89]
- Zhongguancun launched the ZGC Boston Innovation Center as of April 2018, with Beijing government officials in attendance, and its establishment was characterized as important to "build the ecosystem of Zhongguancun's overseas collaborative innovation resources."[90]

The potential benefits and negative externalities of these engagements via venture capital and incubation should receive further consideration going forward, given the clear linkages to government priorities and initiatives to advance Chinese indigenous innovation. Even when there is not evidence that a particular mechanism has been exploited thus far for tech transfer in ways that are illegal or obviously concerning, the access to and knowledge of prioritized technologies can still be beneficial to future targeting and acquisitions. Potentially, as Chinese investments are subjected to greater scrutiny, the focus of tactics for tech transfer could shift further towards these alternative techniques for access to tech and talent resources via accelerators and innovation centers. Again, the factor that should raise questions and differentiate these from purely commercial activities is the consistent government involvement in guidance and direction.

Looking to the most direct type of tech transfer, selected examples of targeted acquisitions illustrate how buyers that have may links to the Chinese government or appear to act in furtherance of its priorities have targeted U.S. and global companies and their technologies, in furtherance of state priorities. When attempts at acquisitions in the U.S. are blocked, this targeting can shift to look for comparable companies and technologies outside of the U.S., often in countries where scrutiny and review mechanisms are less rigorous, which highlights the importance of a global approach to these challenges, in close coordination with U.S. allies and partners.

- After several failed Chinese attempts at acquisitions in the semiconductor industry, Atop Tech, known for a cutting-edge automated designer capable of producing high-end microchips, was acquired in bankruptcy proceedings in the summer of 2017 by Avatar Integrated Systems, for which the board chairman is a prominent Chinese steel magnate, without any scrutiny from CFIUS.[91]
- Complete Genomics was acquired in March 2013 by the Beijing Genomics Institute (BGI, 华大基因), which has links to and has received support from the Chinese government,[92] to support its attempts to create a next-generation sequencer.[93]
- As China aims to emerge as a leader in industrial robotics, a priority in "Made in China 2025," there have been a number of acquisitions of robotics companies in the U.S. and worldwide, which include, but are not limited to:[94]
  - ✧ Paslin, an industrial robot integrator based in the U.S., acquired by Zhejiang Wanfeng Technology in April 2016;[95]
  - ✧ Midea Group's acquisitions of Kuka, based in Germany, in January 2017, and Servotronix, an Israeli motion control and automation company, in February 2017;[96] and
  - ✧ HTI Cybernetics, an industrial robotics integrator based in Michigan, acquired by Chongqing Nanshang Investment group, in October 2017.

Targeting and Leveraging Universities:

U.S. and international universities have been a major target of Chinese cyber and, in some cases, human espionage. In the past few years, there have been a number of intrusions targeting universities that engage in sensitive or military research, including Penn State and the University of Virginia.[97, 98] Chinese hackers have continued to target universities, which tend to be tempting as easy targets, including because of limited attention to cyber security, as well as the potential availability of ample IP and data.[o, 99] In some cases, students and researchers have leveraged academic research environments in ways that may contravene U.S. law or academic norms. The potential for negative externalities has been clearly illustrated by the case of Liu Ruopeng (刘若鹏),[p] a Duke PhD student, who allegedly appropriated sensitive research funded by the U.S. military on metamaterials,[100] and then returned to China to fund a highly successful research institute, the Kuang-Chi (光启) Group, which supports the Chinese military in advanced technological developments.[101] In a more typical occurrence, Chinese students and researchers with experience in top U.S. universities are often targeted for recruitment through Chinese state talent plans and by Chinese companies.[102] Although the openness of university environments is integral to the greatness of the U.S. education systems, the potential for risk highlights the importance of further engagement with academia in order to raise awareness and enhance appropriate safeguards and precautions.[103]

Although there are compelling reasons to welcome Chinese students to the U.S. – and to encourage them to stay and contribute to American innovation – it is clear that there are instances when the

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[o] For instance, just this month, reports emerged that Chinese hackers have infiltrated Australian National University, potentially compromising the university's research and intellectual property.

[p] Please note that I consider this case to be an extreme example. It is difficult to estimate how many such incidents have occurred in the past few years.

U.S. education system has been exploited in ways that are problematic at best or, at worst, even contribute to Chinese military modernization. These incidents are not reasons to direct suspicion towards or shut the door on Chinese students and scientists,[104] and a case-by-case response to these incidents is the best way forward. However, when students from PLA universities or Chinese universities that are closely linked to Chinese defense technological development study and pursue research in the U.S., there is a more definite rationale for stronger screening mechanisms to limit access to those with such direct linkages to Chinese military research. Notably, the PLA's National University of Defense Technology (NUDT, 国防科技大学) has been quite active in sending doctoral students, and also undergraduates, overseas, including to the United States, United Kingdom, and Australia, among others.[105]

- As of the fall of 2017, there were at least two NUDT PhD students studying at U.S. universities, one of whose research focused on big data.[106]
- At NUDT's Center for Interdisciplinary Quantum Information Science (量子信息学科交叉中心), one prominent researcher returned to "devote all his energy to the military,"[107] after pursuing post-doctoral research at Stanford University.[108]
- A researcher with the PLA's NUDT was recently a visiting scientist at a U.S. national laboratory, where his research focused on optics and metrology.[109]

Pursuant to China's Thousand Talents Plan (千人计划), launched in 2008,[110] over 7,000 scientists and researchers are estimated to have been attracted back to China, receiving substantial financial incentives,[q] on a permanent or temporary basis, as of January 2018.[111] Similarly, the Thousand Youth Talents Plan concentrates on the recruitment of younger scientists. While examples of such targeted recruitment of talent through these plans and otherwise abound, certain instances, by way of illustration, raise questions about the possibilities for tech transfer in sensitive and strategic technologies. In particular, certain U.S. scientists have been recruited to take appointments at Chinese universities and to contribute as co-investigators of Chinese laboratories that are linked to dual-use technological development.

- A leading expert on quantum physics and materials, such as topological insulators, from a prominent U.S. university was recruited through the Thousand Talents Plan to become a professor and the co-investigator of a laboratory at Tsinghua University, and later awarded the People's Republic of China International Science and Technology Cooperation Award.[112]
- A professor at a public research university who had received U.S. military funding for research on bionic robotics later became a co-investigator of a key laboratory supported by the Shenzhen municipal government and also apparently co-founded a company based on that research.[113]

[q] Typically, successful applicants receive a bonus of 1 million RMB ($151,000) to start, and then can apply research funding of 3–5 million RMB (about $450,000 to $740,000. Those foreign scientists who are recruited receive further incentives, such as subsidies for accommodations.

Chinese funding for research at U.S. universities also raises questions about potential externalities and should receive further scrutiny going forward. For instance, Huawei has actively funded research worldwide and pursued academic partnerships through its Huawei Innovation Research Program.[114] In the U.S., Huawei has invested about $10 million each year in research, including on 5G development, collaborating with at least fifty universities that include Harvard University, Stanford University, and the Massachusetts Institute of Technology (MIT).[115] In 2017, Huawei devoted $1 million to funding research on AI at the University of California, Berkeley.[116] Although many universities may welcome this source of funding, at a time when U.S. government expenditures on basic research have been declining, there is a need for greater transparency about ways in which that funding may enable access to sensitive data and research, as well as the end uses of IP generated through these research collaborations.

Some U.S. universities have created joint laboratories with Chinese universities or laboratories that have clear links to military research or support state priorities.

- The Tsinghua-Michigan Joint Center for Quantum Information (JCQI) seeks to leverage the respective advantages of Tsinghua and the University of Michigan in quantum information in order to establish a "first-class platform and center for talent cultivation" in quantum information, while also "promot[ing] China's research in quantum information to the world-leading level."[117]
    - ✧ In this context, it's worth noting that Tsinghua is also involved in the development of quantum technologies for national defense applications, in partnership with China's National University of Defense Technology.[118]
- In June 2017, MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) announced a new five-year collaboration with iFlytek, a Chinese national champion known for its leadership in smart voice technologies, including making 'China's Siri.'[119] Their researchers will collaborate on projects, including computer vision, speech-to-text systems, and human-computer interaction.[120]
    - ✧ iFlytek's technologies have been leveraged by China's Ministry of Public Security to enable voice biometric collection, providing capabilities threaten privacy and that have the potential for abuse.[121] The company has not yet responded to concerns and questions raised by Human Rights Watch on that point.[122]
- In September 2017, Carnegie Mellon University (CMU) and LAB Venture signed an agreement to establish the Chengdu Institute of Carnegie Mellon University (CICMU) in the Chengdu Hi-tech Zone, where it will serve as "a global platform of technology transfer."
    - ✧ CMU will provide funding, management, expertise, and human resources for the institute, which will focus on AI and smart infrastructure.[123]

Research Collaborations and Commercial Partnerships:

U.S. companies that engage in joint ventures and partnerships in China can face risks to their technologies in some cases or have become involved in potentially problematic engagements with counterparts that have linkages to the military in other instances.[r, 124]

- In June 2015, NVIDIA established a strategic partnership with Sugon (曙光), an enterprise established under China's 863 Plan, and the CAS Institute of Computing Technologies, focusing on deep learning, which involved creation of joint laboratories and release of deep learning projects.[s, 125, 126]
  - ✧ Although this ongoing partnership has primarily focused on commercial applications of deep learning, such as to biomedical data,[127] it is worth noting that Sugon has also been involved in the development of military applications of AI, including in command and control, supporting military-civil fusion.[128, 129, 130, 131]
- Google's China AI Center, announced in December 2017,[132] has started to pursue engagement with several Chinese universities. In particular, Tsinghua's new Institute for Artificial Intelligence plans to pursue cooperation with Google,[133] at a time when the university is also deeply and institutionally committed to China's national strategy of military-civil fusion in AI,[134] including with a high-end laboratory for military intelligence and research funded by the PLA's Central Military Commission.[135]

Such partnerships and research engagements require careful structuring and implementation to mitigate risks of tech transfer or unintended externalities.

Policy Considerations and Recommendations

The United States has benefited tremendously from the openness and inclusivity of our innovation ecosystem, but it is vital to balance that openness with recognition of the risks and benefits inherent in engagement and 'entanglement' with China. Our policy responses to these issues should thus be highly nuanced and targeted in order to mitigate the risks of collateral damage to our own competitiveness. Given the global nature of these issues, the U.S. must also engage and coordinate with allies and partners in undertaking appropriate countermeasures, which include stricter reviews of acquisitions, investments, and certain collaborations.

Looking forward, the U.S. must not only defend its research and technologies but also go on the offensive, not fearing competition with China, but rather embracing it. That is, the U.S. must recognize and reinforce its own enduring advantages in innovation through the pursuit of policies that have enabled and can revitalize its own innovation ecosystem. These include a focus on STEM education at all levels, robust and sustained investments in basic research, and openness to welcome talented scientists and entrepreneurs, including from China. In the today's strategic competition for technological dominance, the U.S. can win only by sprinting ahead, not just building walls.

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[r] Since this issue has received greater concern and attention in the past, I limit this discussion to highlighting a few recent cases of partnerships in emerging technologies in particular.

[s] Of note, in April 2015, the U.S. government had banned NVIDIA and Intel from selling GPUs to China's four supercomputer centers. However, this ban does not appear to have curtailed NVIDIA's partnership with Sugon, which has continued.

U.S. policymakers should consider a range of policy responses, which might include, but not be limited to, the following recommendations:

Targeted Countermeasures:

- Explore updates and revisions to national export controls, defense trade controls and investment review mechanisms that take into account the unique challenges of dual-use commercial technologies.[t, 136]
  - ✧ Share lessons learned and pursue coordination with allies and partners to account for the global scope and scale of these dynamics.
- Engage in outreach to companies and universities in order to highlight the potential for risk or unintended externalities in joint ventures and partnerships, including through developing and presenting a series of case studies based on past incidents.
  - ✧ Consider reestablishing the now-disbanded FBI National Security Higher Education Advisory Board to facilitate and institutionalize such engagements.[u, 137, 138]
- Enhance and enforce cyber security standards and requirements for contractors and laboratories engaged in sensitive academic research.
- Review recent and existing research and commercial partnerships on strategic technologies that involve support and funding from foreign militaries, governments or state-owned/supported enterprises, evaluating the dual-use risks and potential externalities in each case.
  - ✧ Ensure that these appropriate safeguards are applied to sensitive datasets associated with AI development, including data used for training purposes.
- Consider introducing, or where appropriate adjusting, policies or guidelines restricting those who have received from the U.S. military or government at a certain level from also accepting funding from or collaborating with a foreign military, state-owned enterprise, or 'national champion' that is not an ally.
- Enhance counterintelligence capabilities, particularly by augmenting language and technical expertise, to focus on enforcement.[v, 139]
- Improve visa screening of foreign nationals who plan to study or research sensitive or strategic technologies, targeting scrutiny on the basis of whether or not students or researchers have direct and clear connections to foreign militaries, governments or intelligence services.
  - ✧ Incorporate an independent review mechanism into the process to assess evidentiary standards and mitigate risks of bias in such visa determinations.

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[t] Of note, a case that illustrates these dynamics is Aqueti, a company founded by Duke University scientists who developed a sophisticated gigapixel camera that was originally intended to provide long-range surveillance for the U.S. Navy, with support and funding from the Pentagon. After the founder later struggled to raise money in the U.S., he relocated the company to China, where it has since found a sizable market for use with Chinese police.

[u] Rush Doshi is to be credited for initially bringing this board to my attention. Please see the citation for his perspective on these issues.

[v] For a recent example of successful apprehension and enforcement, see the arrest at the airport of a former Apple employee who had downloaded a plan for a self-driving car circuit board and then booked a flight to China, where he planned to work for and transfer the design to a Chinese self-driving car start-up.

- Identify organizations engaging in talent recruitment that are linked to the Chinese central and local governments or to the Chinese Communist Party (CCP), and require their registration as foreign agents, where appropriate.[w]

Ensuring American Competitiveness:

- Increase and commit to sustaining funding for basic research and the long-term development of strategic technologies.
- Prioritize improving the accessibility and affordability of STEM education at all levels, including creating new scholarships to support those studying computer science, artificial intelligence, and quantum information science, among other priority disciplines.
- Sustain openness to immigration, welcoming graduating students and talented researchers, while potentially offering a fast-track option to citizenship.
- Explore the expansion of alliance coordination and cooperation in innovation, including deeper collaboration in research, development, and experimentation with new technologies and their applications.

[w] I have argued and want to emphasize again that I do *not* believe that scrutiny or restrictions should be imposed against Chinese students and researchers on the basis of national origin alone. When state-driven recruitment, such as through China's talent plans, that is targeted against persons who are of Chinese heritage and/or Chinese citizens is deemed problematic, then the response should be directed against the organizations in question, not the individuals who are being targeted.

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