Testimony before the U.S.-China Economic and Security Review Commission hearing on "China's Challenges and Capabilities in Educating and Training the Next Generation Workforce"

Panel II: "Advancing Growth, Knowledge, and Innovation through Higher Education."

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Co-Chairs Cleveland and Price, distinguished Commissioners and staff, thank you for the opportunity to participate in today's hearing. It is an honor to be here alongside esteemed experts on the different panels. I am currently the Director of Biotechnology programs and a Senior Fellow at the Center for Security and Emerging Technology (CSET) at Georgetown University, where I lead our Biotechnology efforts. For most of my career I have studied China's science and technology (S&T) development and innovation ecosystem, including its efforts to acquire technology and technological know-how, how these efforts have changed over time and the policies and programs China uses to meet its strategic goals.
My testimony today will first address the assumptions that are made about innovation in China, the policies and programs it has put in place to grow its national innovation base–especially those related to human capital–and the implications of these policies for the U.S.-China strategic competition. In particular, I will discuss how our systems differ, and how the role of the state impacts and influences all aspects of China's S&T ecosystem, from universities to its state key labs and its associated industries. I will provide specific examples of how these industry-academia linkages play out in different areas such as AI and biotechnology. Lastly, I'll offer lessons learned, which include:

- Talent development is essential for Beijing to meet its strategic goals and will be a major piece of US-China competition. China has made talent development and acquisition–including leveraging its diaspora–a central part of its technology development and acquisition strategy since the country's "opening" around 1978.
- China's system is not the same. It takes a holistic approach to developing technology—blurring the lines between public, private, civilian and military. Our policies and mitigation strategies need to reflect this reality.
- We must not conflate return on investment (ROI) and commercial success with innovation. Sometimes China's goals are ROI and commercial success, but meeting its strategic goals–even in the commercial area in the short term–does not necessarily mean return on investment or commercial success. Beijing has shown a willingness to accept inefficiencies to meet broader goals. An example of this is its development of 5G and DNA sequencing.
- China will gain the advantage in technology competition if we don't acknowledge and address those areas where national security and market forces diverge.
- Giving scientists a problem to solve is not the same as giving them a solution. Political control is not the same as scientific control. Scientists–and innovation–will thrive with funding, lab space and freedom to pursue their craft.

- Regardless of their personal views, Chinese scientists, businesspeople and officials have to respond to the government or security services if they are asked for information or data. China intimidates and harshly silences its critics—this has only grown more so in the past few years. This increasingly includes its citizens abroad.

Does innovation matter?

How the United States can compete in the 21st century is perhaps one of the most vexing challenges on the minds of policymakers and academics today. The looming challenge of a nation-state keen on dominating the key technology areas of future industries and warfare, paired with an increasingly globalized scientific base, creates unique challenges for the United States beyond what it faced in the Cold War. Human capital is at the center of this competition. However, before diving into the specific questions regarding talent and higher education that are the focus of today's hearing, I believe it is essential to address the "proverbial" elephant in the room when talking about China–do they have the capacity for "true," often inferred as "Western-style," innovation? Underlying this broader debate regarding China's capabilities are a number of assumptions that include:

- "Western-style innovation"—along with democracy—is necessary for "true" innovation
- China needs a Western development model to succeed, including venture capital, institutions such as DARPA and an efficient economy.
- Chinese scientists are not creative or risk takers because of the education system and bureaucracy.

This is more than a philosophical debate because whether a company, government or individual thinks China is innovative or not impacts the risk calculation one makes in dealing with China. This has shaped early interactions and willingness to share technology and train students, researchers and technicians. If you believe you are 5-10 years ahead and you inherently will "always out innovate them" you will make a different risk calculation than if you are dealing with a peer competitor.

Why does this matter? Human capital is the driver of discovery and future industry and increasingly a fundamental part of U.S.-China strategic competition. Xi has called human capital the "first resource"[i] and China's policies reflect this. It is essential to the "art" part of science, manufacturing and other key industries. Tacit knowledge—technological knowhow—is as important as funding and the actual physical technology or data. This is why China, in addition to implementing talent programs to bring back experts to train the next generation of domestic talent, has also focused on maintaining access to U.S. research institutions and universities. China views Western universities as an entry point into the U.S. innovation base.

The way China has implemented this vision since its opening in the late 1970's has changed over time but its goal has remained the same—creating a technically proficient workforce with the right number of "high fliers" to drive weapons programs and new industries. It has accomplished this through a series of central government policies and talent programs that both focus on bringing back experts to drive strategic research programs and training the next generation of Chinese scientists.[ii]

While most of you have probably heard of the Thousand Talents program—it is just one of hundreds of talent programs China has initiated that target different age groups and technology areas. Other central government programs focused on fostering talent and its higher education system include[iii]:

- China's National Medium and Long-term Talent Development Plan (2010–2020). It states that talent is core to the country's social and economic development and sets detailed national talent targets. It also has sections devoted to training of scientists at all levels and how to support an ecosystem where they can thrive.[iv]
- The 2017 "Plan to Build a National Technology Transfer System." This plan highlights the importance of the acquisition of "high-level overseas talent"—both ethnic Chinese scientists from abroad and other foreign scientists.
- The 2016 "Planning Guide for Manufacturing Talent Development." This is a joint plan to import "1000" foreign experts able to make "breakthrough" improvements, via talent programs and other venues. This plan also emphasizes recruiting people from "famous overseas companies."
- The 2004 Chinese Association for Science and Technology's "HOME Program" (or Haizhi Plan, 海智计划)," was instituted to "Help Our Motherland through Elite Intellectual Resources from Overseas," and is supported by China's central and local governments. Its 2019 goals include 29 different projects.
- Talent programs to develop specific high-tech areas such as biotechnology, integrated circuits, and "next-generation" artificial intelligence. Each such program highlights the role it sees for foreign talent such as training, research and mentoring students. [v]

As for the advantages and disadvantages in China's higher education system, it is important to be clear what part of the system we are most interested in—undergraduate education or graduate education, STEM or liberal arts; top tier or less well-known. This is because the advantages and disadvantages will be different across the different segments of its system. There will also be differing impacts on China's strategic goals. Advantages in China's system include:

- The ability to set national curricula and prioritize certain technical areas;
- The ability to direct students to go into different areas of study;
- The ability to mobilize all aspects of the S&T infrastructure, including universities, institutes and companies, to work towards a common goal;
- The ability to use its market to extract help from foreign companies to train and educate students and faculty; and
- The political will to maintain sustained investments over time.

Some disadvantages in China's system include:

- A rigid approach to curriculum and teaching;
- A highly stratified education system with quality dropping significantly outside of the top tiers; and

- Lack of traditional academic freedom.

Criticisms of China's current education system, while in some ways accurate, also fail to recognize that factors can be both true and untrue depending on which part of China's system are focused on. Its top tier can continue to foster military modernization and economic development–including companies that compete with U.S. companies. At the same time its lower tier can struggle–they are not mutually exclusive.

Building an Innovation Foundation: State Key Labs, Industrial Clusters and the Interconnectedness of China's system

China's S&T system is more interconnected and holistic than the U.S. system—blurring the lines between public, private, civilian and military. [vi] One piece of this system that China is developing as a way to foster interdisciplinary research is the State Key Labs (SKL). SKLs play a key role providing the "bridge" over the valley of death and additional training for China's scientists. China's SKL system comprises hundreds of the country's most elite research facilities supported by universities, enterprises, and the Chinese Academy of Science. These laboratories, overseen by, and most often co-located with, universities and enterprises within China, receive funding, administrative support, and policy and developmental guidance from China's central government. They serve as a primary driver of China's strategic basic research efforts and ambitious S&T agenda with both commercial and military applications.

The Chinese government manages most SKLs, but an increasing number of laboratories are run by private companies.[vii] In 2012, the Ministry of Science and Technology (MOST) adopted the "Interim Measures for the Administration of Building State Key Laboratories Relying on Enterprises." The scientific fields prioritized by government and enterprise-run SKLs, according to CSET analysis, differs slightly with government labs prioritizing life and earth sciences and enterprise SKLs placing more emphasis on engineering, information, and materials science. Existing entities can be "promoted" to the title of "State Key Laboratory." They are also beneficiaries of China's state-led talent recruitment programs. A recent CSET publication identified 59 SKLs where 10 percent of personnel (304 individuals) were talent plan awardees.[viii]

Another avenue for interconnectedness is the development of what China calls "industrial clusters" (产业集群). These clusters are focused on promoting multi-disciplinary research and integrating researchers, developers and government entities. China's central government offers funding, space, talent, and other resources to clusters that focus on strategic emerging industries. They consist of small- and medium-sized enterprises in the same or related industry as well as universities, SKLs and larger state-supported enterprises such as BGI and Huawei. [ix]

China's focus on Strategic Emerging Industries is an additional avenue for creating interconnectedness throughout its S&T ecosystem. These policies, the first issued in 2013 and the second issued in 2020, lay a blueprint for its future goals of dominating key sectors through interconnectedness and central planning. These plans focus on securing the China market first on the way to building global champions. Talent plays a key piece in this area.

Finally, China's most well-known policy that fosters interconnectedness is military-civil fusion. China says it will use any knowledge or technology it acquires for its military. This is not conjecture, profiling, or analysis, but China's stated position for decades. From early military-civilian integration (军民结合) policies to the more recent military-civilian fusion (军民融合), China takes a holistic approach to development, blurring what is civilian, what is military, what is private and what is public. This impacts the basis for entry of Chinese students and post-docs into U.S. labs because of China's ability to compel citizens to share information. It also challenges existing export and visa policies that build their restrictions around affiliations with a military end-user but make exceptions for civilian uses.

The "13th Five-year Plan for Military and Civil Fusion"[x] was established in 2017 and focused on emerging technologies. The plan specifically calls for a "cross-pollination of military and civilian technology in areas not traditionally seen as 'national security issues,' such as quantum telecommunication and computing, neuroscience and brain-inspired research," and states that such projects will be supported by foreign outreach initiatives.

China's ability to use its research ecosystem and leverage talent to pioneer novel and foundational innovation and knowledge on the one hand, and helping to diffuse innovations throughout industry and the economy on the other, is mixed. In many areas, developments are still nascent and the impact on the economy is limited. Below are some examples of how these policies have taken hold and the kinds of relationships that have been established:

- BGI Group is a Shenzhen-based gene sequencing company with a global network of more than 200 subsidiaries. The growth and success of BGI demonstrates not only the holistic nature of China's S&T system, combining private and public sectors and the military, but also how sustained support can impact a key emerging industry. Its collaborations give BGI—and China—access to genomic data worldwide.[xi]

- Novogene (诺禾致源科技) is a genomic services provider that claims to have the world's largest sequencing capacity. Its founder, Li Ruiqiang (李瑞强) was a senior executive at BGI and is an expert in genomics. Novogene received investments from state-owned entities including CMB International Capital Corporation, China Merchants Bank, and the State Development and Investment Corp. [xii]

- The Chinese Academy of Sciences Institute of Computing Technology (ICT) combines AI and medical research at its Bioinformatics Research Group (生物信息课题组) housed under ICT's Advanced Computing Research Laboratory, and the Medical Imaging, Robotics, Analytical Computing Laboratory & Engineering (医疗影像机器人与分析计算研究组), a subdivision of ICT's Key Laboratory of Intelligent Information Processing.[xiii]

- Shanghai Jiaotong University's Artificial Intelligence Institute houses a Center for Smart Healthcare (智慧医疗研究中心), which "aims to empower clinical medicine and medical services with AI technology," researches "new paradigms of human-machine interaction," and develops "deep learning services for clinical diagnosis." The center applies AI to disease prediction and a variety of health-related tasks.

- Nankai University College of Artificial Intelligence (南开大学人工智能学院) hosts the Tianjin Municipal Key Laboratory of Intelligent Robotics (天津市智能机器人技术重点实验室). Research and development (R&D) conducted at this laboratory includes medical and service robotics for surgery and rehabilitation support, brain-computer interfaces, and micro and nano detection for life sciences.[xiv]

This leads us to the questions that the Commission has asked regarding how China uses incentive structures and funding to ensure scientists, researchers and developers' work is in alignment with China's "top-down techno-industrial ambitions" and how it differs from that in the United States. The Chinese government, through a multitude of policies and programs, provides a demand signal for certain technology areas. China's national S&T goals are set by committees under that state council that include all aspects of its S&T infrastructure–these are experts in specific fields that are setting these goals. The policies outlined previously provide blueprints for what the Chinese government prioritizes but does not tell scientists how to solve these problems. Giving scientists a problem to solve is not the same as giving them a solution.

By incentivizing and creating the environment where researchers, developers and producers are co-located, China hopes to be able to fill shortcomings related to commercializing and developing key sectors. This model has proven successful in the past. Bell Labs is one example. As highlighted in Jon Gertner's *Idea Factory*, some of the key advantages that allowed Bell Labs to thrive were: long development timelines, constant funding, and a multidisciplinary environment. [xv] These are the elements China is putting in place through the plans I have just discussed.

China's system is also different because of the role of the state that permeates all aspects of society from Party cells in businesses, including western ones, a Party Secretary at universities, and the social credit system that impacts daily life. Chinese students are sent overseas to learn with a purpose, and its business and S&T collaborations are designed to deliver maximum returns to the state.[xvi] Although Beijing has not always been successful in this endeavor, its strategy illustrates a government with a plan and the political will to take a long-term view of development, invest in infrastructure and people, and put in place the building blocks it needs to support China's economy and military modernization. It is masterful at setting the terms of those engagements to achieve long-term goals determined by the state.

The role of the state also impacts the individual. Regardless of their personal views, Chinese scientists, businesspeople and officials have to respond to the government or security services if they are asked for information or data. China intimidates and harshly silences its critics—this has only grown more so in the past few years. Unfortunately, it also increasingly includes its citizens–scientists, students and business people– abroad, including in the United States.
In comparing our two systems, we must remember that success can look different and also be different. China's approach to S&T development may prove unsustainable in the long-term, but still impact U.S. competitiveness and hurt U.S. interests. It took the Soviet Union 75 years to

fail; in that amount of time China and its market distorting practices can do a lot of harm to the U.S. economy and also continue its military modernization in ways that can impact U.S strategic calculus. There are places where good enough is good enough and when writing a check can impact development timelines or buy your way to the front of a technology field. Perhaps the best explanation for why what China is doing not only works, but undermines the assumptions of the importance of efficiency, is put forth by Kai Fu Lee:[xvii]

> "What these critics miss is that this process can be both highly inefficient and extraordinarily effective. When the long-term upside is so monumental, overpaying in the short term can be the right thing to do. The Chinese government wanted to engineer a fundamental shift in the Chinese economy, from manufacturing-led growth to innovation-led growth, and it wanted to do that in a hurry and the process of pure force was often locally inefficient—incubators that went unoccupied and innovation avenues that never paid off—but on a national scale, the impact was tremendous."

The early stages of development for these new knowledge-based industries–such as AI and biotechnology–will be most critical for government support and policies. These "first-mover" advantages may prove to be so critical that those nations that fail to make similar investments and commitments may have difficulty catching up. This gives centrally funded programs targeting specific new technologies an advantage. An erosion in leadership could constrain Washington's policy options such as the United States' ability to set global technology norms, regulations, and standards, as well as harness and control access to technologies for military purposes. [xviii]

Conclusions:

As we move forward to develop policies to compete with China and foster our own talent development, we must challenge our assumptions of how this should look. China does not need to do things the way the United States has done them and follow the same path to succeed. When formulating policies, it is important to remember that our systems are different and that just because it has a similar name—university, company, court—does not mean it will function the same way ours does. The image of a China forging a unique path that suits its needs at a given time is put forth by Nathan Sivin in his description of post-Mao science, noting that "China has gradually since 1949, by fits and by starts, invented policies towards education and science that reflect its own priorities rather than the expectations of other nations."[xix]

Focusing on extremes in examining U.S.-China capabilities—that innovation can only happen in the private sector and that government has little or no role—ignores the potential levers that policy makers can use to foster and incentivize growth in areas with longer timelines and lower returns on investment than private investors currently tolerate. It also underestimates the impact China's approach can have on its ability to compete and how its efforts can create an unequal playing field and potentially distort developmental timelines because of its heavy hand and proactive involvement. In moving forward, I leave the committee with the following thoughts:

- Innovation comes from doing the research—if we are not doing the research, and cede whole disciplines, we will not be innovative.

- A society cannot be innovative if it isn't training enough students.
- Developing and maintaining big science facilities are essential to the national innovation base.
- It doesn't matter if we did it 40 years ago, if we don't continue to train students, technicians and researchers, as well as invest in the tools of discovery we will not be innovative.
- China's policies and plans form a complementary web of development and industrial policies for emerging technologies—and talent growth—and most importantly build a national innovation base that will be the foundation for future economic growth and military modernization that Beijing controls. It is not where they are today in certain fields, but the rate of change that we should focus on.
- China's policies are increasingly challenging for the United States and its allies to counter with policy measures because most policy measures are tactical and not designed to counter an entire system that is structurally different.

I want to thank the committee again for continuing to discuss this issue. These are hard conversations that we as a nation must have if we are to protect and promote U.S. competitiveness, future developments, and our values. We have to start to think about our national innovation base and fostering domestic talent in terms of what is the greatest value to the nation, not only traditional economic efficiency and lowest cost. China will gain the advantage in technology competition if we don't identify those areas where national security and market forces diverge and take proactive measures to compete.

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[i] State Council, 2017; "Why is Xi Jinping's 'First Resource' so important?" ["习近平眼里的"第一资源"为何如此重要"], *People* [人民网], July 18, 2018, http://politics.people.com.cn/n1/2018/0718/c1001-30155931.html.; 国家技术转移体系建设方案. State Council, 2017; 制造业人才发展规划指南. MOE, MHRSS, MIIT, 2016.

[ii] Hannas et al., "Chinese Industrial Espionage: Technology Acquisition and Military Modernization". Routledge, 2013.

[iii]]"十三五" 生物技术创新专项规划 (*13th Five-year Plan for Biotechnology Innovation*). MOST, 2017; 国家集成电路产业发展推进纲要 (National Integrated Circuit Industry Development Plan). State Council, 2014; 新一代人工智能发展规划. (Next-Generation Artificial Intelligence Development Plan). State Council, 2017; "Why is Xi Jinping's 'First Resource' so important?" ["习近平眼里的"第一资源"为何如此重要"], *People* [人民网], July 18, 2018, http://politics.people.com.cn/n1/2018/0718/c1001-30155931.html.; 国家技术转移体系建设方案. State Council, 2017; 制造业人才发展规划指南. MOE, MHRSS, MIIT, 2016.

[iv] "Medium and Long-Term Plan for Science and Technology Development (2006-2020) [国家中长期科学和技术发展规划纲要 (2006—2020 年)], State Council of the People's Republic of China [中华人民共和国国务院], 2006, http://www.gov.cn/gongbao/content/2006/content_240244.htm.

[v] 十三五" 科技军民融合发展专项规划. MOST, CMC, 2017; "十三五" 生物技术创新专项规划 (*13th Five-year Plan for Biotechnology Innovation*). MOST, 2017; 国家集成电路产业发展推进纲要 (National Integrated Circuit Industry Development Plan). State Council, 2014; 新一代人工智能发展规划. (Next-Generation Artificial Intelligence Development Plan). State Council, 2017

[vi] A history of China's investment programs and policies can be found in the following: Simon and CAO "China's Emerging Technological Edge", Cambridge University Press, 2009; Applebaum et al., "Innovation in China", Polity Press, China Today Series, 2018 and Hannas et al., "Chinese Industrial Espionage", Routledge, 2013.

[vii] "Guiding Opinions on Relying on the Transformation of Institutions and Enterprises to Build State Key Laboratories" [关于依托转制院所和企业建设国家重点实验室的指导意见], PRC State Council, 2006, https://perma.cc/6WYG-3SZQ; Yuntao Sun and Cong Cao, "Planning for science: China's 'grand experiment' and global implications," *Humanities and Social Sciences Communications* 8, Article number 215, 2021, https://www.nature.com/articles/s41599-021-00895-7.

[viii] "Notice of the Ministry of Science and Technology on Issuing the Evaluation Results of 99 Enterprise State Key Laboratories" [科技部关于发布 99 个企业国家重点实验室评估结果的通知], PRC Ministry of Science and Technology, 2018, https://perma.cc/4HB3-Y7VQ.

[iv] "The State Administration for Market Regulation on Issuing the Interim Measures for the Administration of State Key Laboratory Market Regulation: Notice of the 'Interim Measures for the Administration of the National Market Supervision Technology Innovation Center'" [市场监管总局关于印发《国家市场监管重点实验室管理暂行办法》《国家市场监管技术创新中心管理暂行办法》的通知],State Administration for Market Regulation, January 8, 2020, https://perma.cc/ZWE5-7JCX; "Chinese State Key Laboratories," Datenna, https://www.datenna.com/chinese-state-key-laboratories/; Fangjuan Yang, Zheng Liang, and Lan Xue, "Assessing the Effects of the Chinese State Key Laboratory Scheme," 2019 Portland International Conference on Management of Engineering and Technology (PICMET), 2019, p. 2, doi: 10.23919/PICMET.2019.8893820.

[ix] PRC National Development and Reform Commission, 加快推进战略性新兴产业产业集群建设有关工作通知 (Notice on Accelerating the Construction of Industrial Clusters in Strategic Emerging Industries), NDRC 1473, 2019.

[x] Translation of "The 13th Five-Year Special Plan for S&T Military-Civil Fusion Development" ["十三五"科技军民融合发展专项规划], Center for Security and Emerging Technology; "Opinions on the In-Depth Development of Military-Civil Fusion" [军民融合深度发展的意见], General Office of the State Council on Promoting the National Defense Technology Industry [国务院办公厅关于推动国防科技工业], December 2017, https://perma.cc/4M58-X4C2; "'Military-to-civilian' and 'civilian-to-military' pace accelerates, the development of MCF continues to release new momentum" ["军转民""民参军"步伐加快军民融合发展持续释放新动能], China Financial News Network [中国金融新闻网], August 1, 2018, https://perma.cc/B4FH-H2SK

[xi] BGI 华大 in Chinese. The Beijing Genomics Institute, forerunner of the BGI Group, began life in 1999 and continues some of its earlier activities in the Chinese Academy of Sciences as the Beijing Institute of Genomics (北京基因组研究所, BIG). We use the term "BGI" interchangeably to refer to the composite entities; *Reuters* reported BGI used a military supercomputer to analyze genetic data obtained from its sales of prenatal tests to map the prevalence of viruses in Chinese women, look for indicators of mental illness, and genetically identify Tibetan and Uyghur minorities. BGI published at least twelve joint studies on the tests with the PLA since 2010. (Kirsty Needham and Clare Baldwin, "Special Report: China's Gene Giant Harvests Data from Millions of Women," *Reuters,* July 7, 2021.

[xii] https://en.novogene.com/about/about-novogene/; "Novogene," https://www.crunchbase.com/organization/novogene-corporation/company_financials.

[xiii] http://bioinfo.ict.ac.cn/; "About Us," http://miracle.ict.ac.cn/.

[xiv] https://ai.nankai.edu.cn/xszx/tjsznjqrjszdsys.htm.

[xv] Co-locating scientist from different disciplines and researchers and developers has been flagged as a key characteristic of building an innovation foundation according to Mervin Kelly, Bell Labs executive and President from 1925 to 1959.

[xvi] Adopted from Hannas et al., "Chinese Industrial Espionage", Routledge 2013.

[xvii] LEE Kai-Fu, "AI Superpowers: China, Silicon Valley and the New World Order" 2018.

[xviii] Mazzucato, Mariana, "The Entrepreneutial State: Debunking Public vs. Private Sector Myths", Public Affairs, 2015.

[xix] Sivin, Nathan from Science in Contemporary China, p.28, ed Leo Orleans, Stanford University Press, 1980.