HEARING ON MADE IN CHINA 2025—WHO IS WINNING?

HEARING

BEFORE THE

U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION

ONE HUNDRED NINETEENTH CONGRESS
FIRST SESSION

THURSDAY, FEBRUARY 6, 2025

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U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION

WASHINGTON: 2025

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HEARING ON MADE IN CHINA 2025—WHO IS WINNING?

THURSDAY, FEBRUARY 6, 2025

U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION

Washington, DC

The Commission met in Dirksen Senate Office Building, Room 562, and via videoconference at 9:30 a.m., Vice Chair Randall Schriver and Commissioner Michael Kuiken (Hearing Co-Chairs) presiding.

OPENING STATEMENT OF COMMISSIONER MICHAEL KUIKEN, HEARING CO-CHAIR

COMMISSIONER KUIKEN: Good morning. Welcome to the U.S.-China Economic and Security Review Commission's first hearing of 2025. First, let me give a few thank-yous.

Thank you to our witnesses for sharing your expertise and for the work you have put into your testimonies. Thank you to the Senate HELP Committee for giving us this beautiful hearing room. Thank you to the Senate Recording Studio for their assistance livestreaming this event. And most importantly, thanks to our staff for pulling together everything that happens today.

As a reminder to everyone attending here in person or listening online, the testimonies of our witnesses are available on the Commission's website, USCC.gov.

Having written and listened to opening statements for two decades, I can tell you the ones delivered by Commissioner Schriver and I are the least interesting, so I will keep this very short. Today's hearing is intended to get to the heart of our competition with China. We will examine China's plan to become a manufacturing and innovation superpower.

Ten years ago, President Xi and China's State Council issued a Made in China 2025 Initiative. The initiative lays out China's plans to lead a new technological and industrial revolution. China has stated that it is not content with the United States as the world's economic and technological leader. Their goal was to become a manufacturing innovation superpower by 2025. Breaking news, folks, it is 2025, and I can report that China has made incredible and alarming progress in the technology areas targeted in the Made in 2025 Initiative.

That leaves us with the question that Commissioner Schriver came up with, which is, who is winning? Today we will evaluate China's progress in three technology areas: biotechnology, aviation, and autonomy. These technology areas demonstrate the breadth of the Made in 2025 Initiative. In biotech, China is building the infrastructure to ruthlessly dominate the biotechnologies of the future. In aerospace, China is working to permanently displace the United States and our European allies. In autonomous technologies, from manufacturing to military applications, China has made incredible strides in deploying frontier capabilities.

Discussing these technologies today will shed light on questions confronting the Commission over the course of this year. It seems China has delivered in spades for the Made in 2025 Initiative. What do the next 10 years look like? What will it take for the United States to

respond to China's whole-of-nation innovation strategy? How should we enlist our friends and allies over the next 10 years to make sure the United States is not going it alone?

We look forward to hearing from the witnesses on these questions and many more. And with that, Commissioner Schriver, you are an excellent partner on this Commission, and I will turn to you for a brief and undoubtedly amazing statement.

PREPARED STATEMENT OF COMMISSIONER MICHAEL KUIKEN
HEARING CO-CHAIR

Hearing on "Made in China 2025—Who Is Winning?"

February 6, 2025

Opening Statement of Commissioner Michael Kuiken

Welcome to the U.S.-China Economic and Security Review Commission's first hearing of 2025. Thank you all for joining us today. Thank you to our witnesses for sharing your expertise and for the work you have put into your testimonies. I would also like to thank the Senate Health, Education, Labor, and Pensions Committee for their assistance in securing this hearing room and the Senate Recording Studio for their assistance livestreaming this event. Finally, I would like to remind everyone attending here in person, and those listening online, that the testimonies from our witnesses are available on the Commission's website. A transcript of this hearing will also be posted to the website.

Today's hearing gets to the heart of our economic and technological competition with China. We will examine China's masterplan to become a "manufacturing superpower": Made in China 2025. Ten years ago, China's State Council issued the Made in China 2025 policy. "Made in China" lays out China's plans to "seize the historic opportunity" to lead the new technological and industrial revolution. China is not content with the United States as the world's economic and technological leader. Their goal was to become a manufacturing superpower by 2025. It's 2025. China has made incredible and alarming progress in the ten technologies they targeted in "Made in China."

That leaves us with the question: who is winning?

Today, we will mark China's progress in three technologies: Biotechnology, aviation, and autonomous technologies. These three technologies demonstrate the full economic, military, and strategic breadth of Made in China 2025.

- China's biotechnology goals focused on laying the foundation for China to dominate the biotechnologies of the future.
- Its aviation goals show how China seeks to replace the United States' economic champions.
- Lastly, advancements in autonomous technologies such as AI-enabled drone capabilities show how China integrated new technologies to build upon industries developed through industrial plans like Made in China 2025.

Discussing these technologies today will shed light on three key questions: What does China's performance to the goals it set for 2025 mean for the next ten years, and is past prologue? What does it take for the United States to respond to China's whole-on-nation innovation strategy? Last, where can we enlist our friends and allies to ensure that in the end, technologies made by democracies and free markets are seen as the global standard?

I would like to thank my fellow Commissioners for their participation, our witnesses for their thoughtful testimony, and the staff for preparing today's hearing. Vice Chair Schriver, it's an honor to co-chair this hearing with you today.

OPENING STATEMENT OF VICE CHAIR RANDALL SCHRIVER, HEARING CO-CHAIR

VICE CHAIR SCHRIVER: Well, thank you, Commissioner Kuiken. Let me join Commissioner Kuiken in thanking our witnesses. We appreciate you putting in all the time that I know you did to prepare these statements. Having reviewed them, they are excellent and I look forward to the discussion.

Let me also welcome Commissioner Brands, your first hearing as a Commissioner. Thank you for stepping up and serving in this capacity.

Made in China 2025 was a bold and audacious project, but it also clearly involved practices and policies that were in violation of China's global trade commitments. The successes of China Made In 2025, which I am sure we will hear much about today, do underline the importance for us and those in Congress and in the government to really take seriously what China's stated ambitions are in technology and in supply chain.

The experience of the past 10 years demonstrates the immensity of the resources that Chinese leaders are willing to deploy towards these objectives, and there is little reason to suspect China's practices will change. The CCP aims to make China a leader in technological innovation and manufacturing, key industries in the future. These are policies not just to achieve domestic growth and self-sufficiency, they are designed to ensure dominance and global dependency on China.

Concerns about Made in China 2025 and related policies are most acute when it comes to technologies that augment China's military modernization. As our witnesses will testify, China pursues numerous overlapping policies in support of its goals, ranging from subsidies to various technology transfer policies to outright theft. However, the integration of civilian technology development with military innovation through military-civil fusion means that these industrial policies must be viewed in the context of Xi Jinping's goal to acquire a world-class military.

So perhaps most important of all this, we need to understand does the nature of this technological competition and the potential security implications of key technologies mean that the United States must develop new measures to boost our capabilities and prevent leakage to China, or can the United States rely on the strength of its innovation ecosystem to simply run faster?

So I look forward to the discussion today and learning from the expertise of our witnesses.

PREPARED STATEMENT OF VICE CHAIR RANDALL SCHRIVER
HEARING CO-CHAIR

Hearing on "Made in China 2025—Who Is Winning?"

February 6, 2025

Opening Statement of Vice Chair Randall Schriver

Thank you Commissioner Kuiken. First, let me join you in welcoming our witnesses and thanking them for participating in the hearing.

Made in China 2025 was an audacious project. It also involved policies that were clearly a violation of China's global trade commitments. The successes of Made in China 2025 underline the importance for Congress, the U.S. government, and really all of China's trading partners to take seriously the Chinese Communist Party's (CCP) stated ambitions in technology and supply chains.

The experience of the past ten years demonstrates the immensity of the resources Chinese leaders are willing to deploy toward these objectives. And, there is little reason to suspect the China's interventionist approach will lessen over the next decade. The CCP aims to make China a leader in technological innovation and manufacturing key industries of the future. These policies are not just to achieve domestic growth and self-sufficiency; they are designed to ensure dominance and global dependency on China.

Concerns about Made in China 2025 and related policies are most acute when it comes to technologies that augment China's military modernization. As our witnesses will testify, China pursues numerous, overlapping policies in support of its goals, ranging from subsidies to various technology transfer policies to outright theft. However, the integration of civilian technological development with military innovation through military-civil fusion means that these industrial policies must be viewed in the context of Xi Jinping's goal to acquire a "world-class military." From autonomous technologies, such as drone swarming, to the development of new materials for aerospace applications, Chinese leaders have linked becoming an innovative nation with gaining a battlefield advantage.

Clearly, the United States and allied countries need to be more proactive to ensure that China cannot dominate more industries like it has done in electric vehicles and solar panels. While the United States did wake up to the problem and begin more aggressive use of export controls and other trade tools, those came very late in the process. China's advances in critical technologies like semiconductor manufacturing and artificial intelligence are reminders to the U.S. and like-minded countries of the need for quick and decisive action. The stakes are too high.

Competition for leadership for certain technologies like genetic engineering or human-like artificial general intelligence is fierce. In many cases, the first country who can deploy these technologies will see a significant advantage across multiple domains of commercial and military competition. The witnesses on our panel looking ahead to the next decade of U.S.-China competition have been asked to answer several important questions. Perhaps the most important is this: Does the nature of this technological competition, and the potential security implications of key technologies, mean that United States must develop new measures to boost our capabilities and prevent leakage to China or can the United States rely on the strength of its innovation ecosystem to run faster than China?

I look forward to the discussion today and learning from the expertise of our witnesses.

PANEL I INTRODUCTION BY VICE CHAIR RANDALL SCHRIVER

VICE CHAIR SCHRIVER: I have the privilege of introducing our first panel. The first panel will provide a deep dive into how Chinese industrial policy developed three technologies that were either explicitly targeted in Made in China 2025 or relied on technologies that benefitted from this policy. Those three areas are biotechnology, aviation, and autonomy.

We will start with Dr. Drew Endy. He is the Science and Senior Fellow at the Hoover Institution, and Martin Family Fellow in Undergraduate Education at Stanford University. Dr. Endy's testimony will evaluate China's progress in biotechnology and its future targets and capabilities in synthetic biology.

Next we will hear from Mr. Richard Aboulafia. He is the Managing Director at AeroDynamic Advisory. He will discuss China's efforts in aviation, especially its challenges developing civilian passenger jets.

Finally we will hear from Mr. Sunny Cheung, Fellow for China Studies at Jamestown Foundation. Mr. Cheung will discuss the evolution of autonomous technologies related to Made in 2025 and their military applications.

Thank you all again, and the Commission is looking forward to your remarks.

Dr. Endy, we will begin with you.

OPENING STATEMENT OF DREW ENDY, SCIENCE AND SENIOR FELLOW, HOOVER INSTITUTION AND MARTIN FAMILY FELLOW IN UNDERGRADUATE EDUCATION, STANFORD UNIVERSITY

DR. ENDY: Vice Chair Schriver, Co-Chair Kuiken, Commissioners, thank you for inviting me.

I want to talk about the cost of time. In 2012, I was leading the United States delegation on synthetic biology as part of a trilateral effort with the National Academies to develop a strategy for synthetic biology. Our partners were the United Kingdom and China. Our mission was to create a strategy that could be used to win the future via emerging biotechnologies. We succeeded. We also succeeded in getting London and Beijing to adopt our strategy and begin to implement it. We failed in Washington. That was strange. That was also 13 years ago.

Since then, China has taken an all-of-nation approach to advancing biology as a technology. Why is this? President Xi is very clear about China's high-level needs and goals, resilient supply chains, economic self-sufficiency, solving the scourge of infectious disease, food security for a nation that has four times as many people as the United States but only three-quarters as much farmland, social stability in a world and reality that is increasingly volatile. 21st century biotechnologies are arriving on time and are directly responsive to each of these high-level needs.

Just as software creates the digital world, biology grows the living physical world, and biotechnology is what allows people to partner with biology to grow ever more of what we need. McKinsey estimates that by midcentury up to 60 percent of the physical inputs to our economy will be grown with modern biotechnologies. It is not just the foods and the medicines and the fuels. It is the seat belts. It is the computers. It is the archival data storage systems. It is the thing you could never imagine would be encoded in DNA and grown.

What choice did China have 10 and 20 years ago but to go all in on emerging biotechnology?

So what does an all-of-nation approach to advancing biotechnology look like? We hear about military-civil fusion and know how powerful that is, but all-of-nation is bigger than MCF. It looks like this. Real estate families donate billions of dollars to convert nine-story shoe factories in Shenzhen into best-in-the-world genomics facilities. That is how we got BGI. President Xi directly exhorting students and entrepreneurs with very clear statements about the importance of biotechnology. These are hanging in the lobbies of tech centers for decades. When you walk in the building and decide what type of entrepreneur do you want to be, maybe you should be a biotech entrepreneur, not this year, not two years ago, but over a decade ago. Compare that with the four administrations it took for us to get an executive order signed in the United States about advancing biotechnology.

It also looks like this, parents with young kids hiring tutors to secure their children's livelihoods. What sort of tutors are we talking about? Genetic engineering. Why? So that when they get to college they have a better chance of getting on the genetic engineering team, not the basketball team, the genetic engineering team. That is what an all-of-nation approach looks like.

So where are we now? Let's consider biotech ecosystem as a four-layer cake -- education, research, entrepreneurship, manufacturing. We can observe the following. Most teams in the genetic engineering Olympics I started at MIT 22 years ago, they are from China. According to the Australians, most of the research in synthetic biology that is the most impactful is published by Chinese scientists. It used to be the United States. China surpassed us apparently

in 2017.

That ground that was shaking last month in San Francisco, thankfully it wasn't the San Andreas, but it was what was going down at JPMorgan Healthcare, where, for the first time, pharmaceutical innovations were arriving from China.

There is also the vibrant biomanufacturing ecosystem that is making money in China, and they are making money with low-value products, with low margins, poised to uptake higher-value products that can't be brought to scale for manufacturing in the United States. Incredible progress by incredible people, working incredibly hard with incredible support.

If Lin-Manuel Miranda had been writing a different musical 10 years ago, we would have heard words like "It must be nice." It must be nice to have President Xi on your side, if you were in biotech.

So I want to talk about the cost of time again. Thirteen months ago, I was in Washington meeting with another commission, the National Security Commission on Emerging Biotechnology. Their work takes time, and I am looking forward to their forthcoming report, and they are an A-plus team, and I know they are working incredibly hard.

But over another year has passed and here we are, still mostly talking about doing something about emerging biotechnologies. Maybe one day. This is strange. How about this instead? Why don't we simply agree that the Silicon Valley for 21st century biotech will be near Shenzhen.

If, instead, we care to compete we have less than 1,000 days to make a difference. Even the next year is important. In fact, the next 100 days are important, and tomorrow is important when you meet them.

I have offered eight specific policy recommendations in my written testimony, but I just want to emphasize a common theme that is a puzzle we have got, that if we could unwind it would do the most to help the United States compete in biotech. Anyone who is a student of history of emerging technologies knows that we win when we take the very precious public treasure and invest it in the high-leverage foundational work, and then we let our entrepreneurs compete on top of that. We win over and over again by doing that -- computing, internet, you name it.

Somehow, though, with biotech we have gotten ourselves turned around, and the reason is pretty straightforward. The applications of biotechnology are so urgent -- cure the disease yesterday, get more biofuels right away -- that the public treasure tends to go in the applications layer, and then we miss on the high-leverage foundational stuff. If we could reverse that we would be much more efficient, we would be much more effective, we would be much more competitive. We, instead, hemorrhage appropriations on the apps.

Please help. Thank you again for your invitation and for your service. I look forward to your questions.

VICE CHAIR SCHRIVER: Dr. Endy, thank you very much.

PREPARED STATEMENT OF DREW ENDY, SCIENCE AND SENIOR FELLOW, HOOVER INSTITUTION AND MARTIN FAMILY FELLOW IN UNDERGRADUATE EDUCATION, STANFORD UNIVERSITY

DREW ENDY[1]

STRANGE COMPETITION

A Statement of Evidence Written in 2025

Testimony[2] presented before the
U.S.-China Economic and Security Review Commission

Hearing on "Made in China 2025—Who Is Winning?"

6 February 2025

[1]Drew Endy, Ph.D., is the Martin Family University Fellow in Undergraduate Education (Bioengineering), Science & Senior Fellow (by courtesy) of the Hoover Institution, Core Faculty & Senior Fellow (by courtesy) of the Center for International Security & Cooperation of the Freeman Spogli Institute, and faculty co-director of degree programs for the Hasso Plattner Institute of Design, Stanford University.

[2]The views expressed herein are solely those of the author and do not necessarily reflect the opinions of any organization or institution they may be affiliated with.

STRATEGIC CONTEXT

Biology allows near-boundless possibilities. The composition and control that software provides the digital world is realized by biology in the physical world. Natural living systems operate and manufacture materials with atomic precision on a planetary scale, powered by ~130 terawatts of energy self-harvested via photosynthesis.[3]

Biotechnology enables people to change biology. Domestication and breeding of plants and animals for food, service, and companionship began millennia ago. Gene editing, from recombinant DNA to CRISPR, is used to make medicines and foods, and is itself half-a-century old. Synthetic biology is working to routinize composition of bioengineered systems of ever-greater complexity.[4,5] Biotechnology goods and services already account for ~5% of the United States' economy; foods, fuels, materials, and medicines are the major product categories.[6]

Up to "60% of the physical inputs to the global economy"[7] could be made via biotechnology by mid-century, generating ~$30 trillion annually in mostly-new economic activity.[8] Emerging product categories include consumer biologics (e.g., bioluminescent petunias,[9] purple tomatoes,[10] and hangover probiotics[11]), military hard power (e.g., brewing energetics[12]), mycological manufacturing (e.g., mushroom 'leather'[13]), and biotechnology for technology (e.g., DNA for archival data storage[14]). Accessing future product categories will depend on unlocking biology as a general purpose technology[15] (e.g., growing computers[16]), deploying pervasive and embedded biotechnologies within, on, and around us (e.g. smart blood,[17] skin vaccines,[18] and surveillance mucus[19]), and life-beyond lineage (e.g., biosecurity at birth,[20] species de-extinction[21]).

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[3]For context human civilization consumes "only" ~20 terawatts excluding the energy embedded in food and other biomaterials sourced directly from the land and oceans.
[4]https://doi.org/10.1038/s41467-023-40199-9
[5]https://doi.org/10.1038/s41586-020-2650-9
[6]https://www.nationalacademies.org/our-work/safeguarding-the-bioeconomy-finding-strategies-for-understanding-evaluating-and-protecting-the-bioeconomy-while-sustaining-innovation-and-growth
[7]https://www.mckinsey.com/industries/life-sciences/our-insights/the-bio-revolution-innovations-transforming-economies-societies-and-our-lives
[8]https://web.archive.org/web/20250116082806/https:/www.whitehouse.gov/wp-content/uploads/2024/11/BUILDING-A-VIBRANT-DOMESTIC-BIOMANUFACTURING-ECOSYSTEM.pdf
[9]https://light.bio/
[10]https://www.norfolkhealthyproduce.com/
[11]https://zbiotics.com/
[12]https://serdp-estcp.mil/focusareas/3b64545d-6761-4084-a198-ad2103880194
[13]https://www.mycoworks.com/
[14]https://dnastoragealliance.org/
[15]https://www.scsp.ai/2023/04/scsps-platform-panel-releases-national-action-plan-for-u-s-leadership-in-biotechnology/
[16]https://www.src.org/program/grc/semisynbio/semisynbio-consortium-roadmap/
[17]https://www.darpa.mil/news/2024/rbc-factory
[18]https://med.stanford.edu/news/all-news/2024/12/skin-bacteria-vaccine.html
[19]https://2020.igem.org/Team:Stanford
[20]https://dspace.mit.edu/handle/1721.1/34914
[21]https://colossal.com/

For President Xi Jinping, biotechnology is arriving on time and in ways that are directly responsive to China's highest-level needs and goals including: (i) "complete domestic circulation" of China's economy, (ii) "improve and stabilize" supply chains, (iii) "improve the mix of scientific and technological inputs and outputs," (iv) "ensure harmony between humans and nature," and (v) "develop a bottom-up (public health) system that ensures early detection, warning, and response so as to control diseases as they arise."[22] When Xi wrote during a pandemic, "we need to attach greater importance to basic research in life sciences, including genetics, genomics, virology, epidemiology, and immunology; accelerate R&D and innovations in relevant medicines and vaccines; and put more emphasis on the use of IT and big data in these fields,"[22] he meant it. Behind Xi's statement, "China must be basically self-sufficient in food production and industrial development. We must never forget this,"[22] is a primal driver; compared to the United States, China must secure food for ~4-fold more people with ~25% less farmland.[23]

CHINA AND BIOTECHNOLOGY LEADERSHIP

There is ongoing debate whether China is already the world leader in biotechnology.[24,25,26] From a policy-maker perspective this debate risks missing the point. The progress of students, scientists, engineers, entrepreneurs, policy makers, and leaders in transforming China into a biotechnology powerhouse over the past twenty years has been extraordinary.[27] Through hard work, ambition, and an all-of-nation effort, China is at-least matching the United States in key elements of biotechnology's "strategic stack" (education, research, entrepreneurship, and manufacturing), is now better organized and supported by Beijing and beyond, and has tremendous momentum. What do these accomplishments look and feel like from a competitive perspective?

Let's start with education. In 2003 I helped launch what became the iGEM competition. Just 16 undergraduates with four instructors at MIT,[28] modeled after Lynn Conway's 1978 VLSI System Design Course that helped launch a revolution in computer chip design.[29] iGEM is now the world-leading synthetic biology "olympics," held in Paris each fall. Teams of students compete to design, build, and test bioengineered systems for useful purposes that they define. Last year's champion from Germany sought to reprogram dandelions to produce carrot-shaped roots in support of sustainable latex production.[30] ~100,000 students have participated so far.[31]

[22]http://en.qstheory.cn/2021-01/14/c_604551.htm
[23]https://www.cia.gov/the-world-factbook/
[24]https://www.labiotech.eu/in-depth/china-biotech-industry/
[25]https://cen.acs.org/business/economy/Chinese-biotech-attracting-global-attention/102/web/2024/12
[26]https://www.biopharmadive.com/news/biotech-us-china-competition-drug-deals/737543/
[27]https://itif.org/publications/2024/07/30/how-innovative-is-china-in-biotechnology/
[28]https://news.mit.edu/2003/blinkers-0226
[29]https://ai.eecs.umich.edu/people/conway/VLSI/MIT78/MIT78.html
[30]https://2024.igem.wiki/marburg/
[31]https://igem.org/

US-based iGEM participation plateaued in 2012 at ~50 teams. It is a lot of work to compete. That same year, potential concerns associated with public perception (i.e., "fear of the fear" of synthetic biology[32]) caused US funding agencies to narrow their focus to "engineering biology." The result was confusion and a "mini ice age" domestically in terms of support for education and research in synthetic biology. The 2015 William & Mary iGEM team was the last champion from the United States. Meanwhile, starting in 2012 China adopted and went all-in on a 20-year roadmap for synthetic biology that was developed in partnership with the UK and US.[33] Ever since, students in China have benefited from all-of-government tailwinds. Last year ~50% of the 400-plus iGEM teams were China-based. Incredibly, some students in California found it easier to participate in iGEM by traveling to China and joining a team there.[34] China has also made significant progress in scaling biotechnology and biomanufacturing education, more broadly.[35]

What about research? The United States remains a world-leader in life science and biotechnology research, broadly defined, but China is overtaking via a focus on emerging biotechnologies. This trend is most noticeable in synthetic biology. From 2003 to 2013 the United States was the undisputed world leader in synthetic biology research. By 2017 researchers in China were reportedly matching their US-colleagues in publishing high-impact synthetic biology research.[36] The trend has apparently continued; researchers in China publish most (>60%) high-impact synthetic biology papers today. What sort of research? The first mirror-image RNA polymerase and ribosome components, as needed to make mirror-life,[37] the first synthetic plant chromosome,[38] and so on. Of note, many of the advances reported by Chinese scientists involve foundational breakthroughs that result in leverage across many aspects of biotechnology (e.g., research towards mirror-life is now a safety and security concern[39]).

How did China's emerging biotechnology research engine get built so quickly and set in high gear? First, China benefited from starting fresh, with most institutional investments and programs launching at or after the dawn of the genomics era. For example, the Beijing Genomics Institute (now BGI Group) was launched in 1999 to help complete sequencing the first draft of the human genome.[40] By comparison, the United States remains burdened with legacy biotechnology research infrastructure and portfolios. Second, China, from President Xi down,

[32]https://doi.org/10.1080/09505431.2014.986320
[33]https://nap.nationalacademies.org/catalog/13316/positioning-synthetic-biology-to-meet-the-challenges-of-the-21st-century; disclosure: I led the US delegation in this trilateral effort.
[34]https://www.linkedin.com/posts/drew-endy-69ba17_last-month-5000-students-met-in-paris-to-activity-7262819887272636416-dVey
[35]https://x.com/NikoMcCarty/status/1774047214081552838
[36]https://techtracker.aspi.org.au/tech/synthetic-biology/historical-performance/
[37]https://www.science.org/doi/10.1126/science.abm0646
[38]https://www.nature.com/articles/s41477-023-01595-7
[39]https://www.science.org/doi/10.1126/science.ads9158
[40]https://en.wikipedia.org/wiki/BGI_Group

has prioritized biotechnology via an "all-of-nation" approach.[41] What does "all-of-nation" look like? All-of-nation involves things like, since 2013, President Xi's portrait hanging proudly in the lobbies of biotechnology centers in Guanming with direct quotes like "artificial life is not only of great significance… but also shows great potential and application." All-of-nation means that the world's-largest genome center can rapidly expand in Shenzhen because Hong Kong real-estate families can afford to quickly forgive a US$1 billion dollar note used to underwrite construction, expansion, and research.[42]

Taken together, China has been building new campuses, institutes, and centers in pursuit of emerging biotechnology. Some of these facilities are now the envy of the world,[43,44] rivaling what the U.S. developed in pursuit of high-energy physics during the mid 20th century. The United States operates nothing like China's emerging biotechnology foundational research platforms. As a result, global coordination of biotechnology's future grand-challenge research projects (e.g., building cells from scratch) now happens in Shenzhen.[45]

Biotechnology entrepreneurship in China is similarly impressive. JP Morgan's Healthcare Conference takes place in San Francisco each January and is one of the most influential events in the industry. Reporting on last month's event STAT noted: "Are we entering a world in which all of the exciting new therapeutics come from China?," and "More than a third of the therapeutic molecules bought by pharma companies came from China last year... That number was zero four years ago," and "Not only were there research parks that dwarfed biotech hubs like Kendall Square in Cambridge, Mass., but the businesspeople and scientists he was reaching out to on the ground were dogged."[46] Similar reports from last month's event are easy to find.[21] Dr. Sandra Barbosu anticipated such reporting, writing in her thoughtful and understated July 2024 report, "China used to be considered a laggard in biotech. But with a comprehensive national strategy and extensive resources now supporting the industry, it is becoming more innovative."[22]

China is also a leader in biomanufacturing at full scale.[47] For example, China is reported to have a majority global share of fermentation capacity for some amino acids, organic acids, and especially vitamins. 90% of the raw ingredients for antibiotics are reportedly manufactured in China. Meanwhile, bio-entrepreneurs in the United States bemoan, "the lack of sufficient US

[41]"All of nation" is a better description for how China approaches biology as a strategic domain compared to "military-civil fusion" (MCF), which is itself impressive (please see the excellent work from State Department on MCF here: https://www.state.gov/wp-content/uploads/2024/11/ISAB-Report-on-Biotechnology-in-the-PRC-MCF-Strategy_Final.pdf)
[42]The families may have recovered more money when the surrounding property values increased.
[43]https://x.com/NikoMcCarty/status/1773685194765250586
[44]https://x.com/NikoMcCarty/status/1774772972999659767
[45]https://isynbio.siat.ac.cn/en/view.php?id=317
[46]https://www.statnews.com/2025/01/15/jpm-conference-biotech-industry-excited-anxious-chinese-biotech-deals/
[47]https://www.daofoods.com/news/l2r8uohyho2vldn15hxqfb8z3gj2f4

manufacturing capacity (full-scale) is causing a backlog of promising innovations that cannot be commercialized."[48]

BIOTECHNOLOGY R&D DEPENDENCIES

The US and global biotechnology research community benefits significantly from ingredients, products, and services provided by China or China-owned firms. For example, phosphoramidites are the chemical ingredients used to synthesize DNA. It used to be that phosphoramidites were sourced starting from salmon milt,[49] typically obtained from the Pacific Northwest or Japan. ~30 years ago new routes to phosphoramidites starting from sugarcane were developed. While the United States maintains on-shore phosphoramidite synthesis capacity,[50] China is likely the cheapest global supplier.

As a US-based academic researcher, my lab routinely contracts with service providers in China. For example, although we primarily order DNA and genes from US-based companies like Twist (California) and IDT (Iowa), for difficult-to-construct genes we find that Genscript (Shanghai) has been our most reliable supplier. Last year, when we sought to understand how the genes of a microbe that lives on the human skin might turn on and off in response to changes in blood glucose levels we used Novogene (Beijing) to carry out rRNA depletion, cDNA library preparation, and sequencing as part of Novogene's Prokaryotic RNA Sequencing service.[51] Why? Novogene's service offering was the best available and allowed one more Stanford bioengineering student to earn her Ph.D.

The Biosecure Act (H.R. 8333) highlighted many more dependencies permeating the U.S. and global biotechnology research ecosystem.[52] As one example, WuXi AppTec (WuXi) is a world-leading contract research, development, and manufacturing organization (CRDMO) serving various biotech markets.[53] Among other offerings, WuXi provides drug discovery, preclinical safety testing, analytical and manufacturing process development, cell line, viral vector, and monoclonal antibody development, cell and gene therapy development, and small molecule and clinical trial material manufacturing as a service.

One concern is that data generated in the course of contracting work with WuXi is or could be used within China for other purposes. For example, in January 2024 Rep. Auchincloss (D-MA 4th District) stated, "The Chinese Communist Party and its affiliated biomedical corporations are operating unethically in the collection of genetic information without consent, and U.S.

[48]https://agfundernews.com/synonym-bio-report-documents-global-gaps-in-fermentation-capacity
[49]https://dspace.mit.edu/handle/1721.1/39657
[50]https://www.thermofisher.com/us/en/home/life-science/oligonucleotides-primers-probes-genes/phosphoramidites/amidite-learning-resources/phosphoramidite-considerations.html
[51]https://doi.org/10.3389/fmicb.2024.1408796
[52]https://en.wikipedia.org/wiki/Biosecure_Act
[53]https://www.wuxiapptec.com/

taxpayers should not be helping to fund those or other nefarious practices."[54] However, the frank reality is that US biotech R&D has become so dependent on CRDMO's like WuXi that strong domestic industry push back helped stall the Biosecure Act in the Senate.[55] Soon after, in December 2024, the Worcester Business Journal reported that WuXi resumed construction of its $300 million facility outside Boston.[56] Imagine if the information technology sector in the US became utterly dependent on cloud servers and services operated or owned by Chinese firms.

CONCERNS OR POTENTIAL CONCERNS

Regarding bio-manufacturing competitiveness, China already has a diverse and robust set of commercial actors who are skilled at making money while making low-value bioproducts; making money by making higher-value products will be easier. China has and continues to invest in state-of-the-art biomanufacturing capacity via an all-of-nation approach. US innovators who prototype novel bio-based processes struggle to access existing domestic manufacturing capacity or the capital needed to build new facilities; the resulting situation creates the risk of an increasingly "brewed in China" future, analogous to what occurred with other technology sectors that failed to scale and sustain manufacturing domestically (e.g., solar panel, batteries, etc). Current USG focus on expanding pilot-scale biomanufacturing will be woefully inadequate if "downstream dollars" fail to flow at the scales needed to enable full-scale biomanufacturing[57].

But biomanufacturing competition is just the "snowflake on the tip of the iceberg." Economic prosperity, environmental health, and national security are all increasingly dependent on biotechnology. The foundational science and engineering practices underlying biotechnology are poised to break through the limitations of an Edisonian (i.e., "tinker and test") era. Biology as a fully-mature technology offers very different opportunities compared to the entrenched biotechnology practices of today. Recall the transition from industrial, to personal and networked computing that began ~50 years ago. Emerging biotechnology promises similar structural transformations today. Twenty-first century biotechnologies could fill a space of opportunity defined by "download (DNA code) and grow (locally)", pervasive and embedded biotechnologies, routinized bioengineering workflows (i.e., "design, build, work" replacing "design, build, test, learn"), life beyond lineage, AI-enabled biotechnology, and biotic citizenship[58] (e.g., biotechnology becomes cool).

Imagine such a world in which the United States is not the undisputed biotechnology leader. Imagine a world in which the "Silicon Valley" of twenty-first century biotechnology is in

[54]https://auchincloss.house.gov/media/press-releases/release-auchincloss-joins-bipartisan-group-of-select-committee-members-in-introducing-house-and-senate-bills-to-ban-foreign-adversary-biotech-companies-including-bgi-group
[55]https://www.jdsupra.com/legalnews/biosecure-stalls-will-not-become-law-in-9534650/
[56]https://www.wbjournal.com/article/wuxi-construction-resumes-at-delayed-300m-facility-as-biosecure-act-stalls
[57]For every dollar invested in pilot scale biomanufacturing we should expect, on average, twenty dollars will be needed to realize full scale biomanufacturing.
[58]https://bio4e.stanford.edu/report

Shenzhen not California. At best, we will experience increasing economic dependencies and security vulnerabilities. At worst, The United States will slip as a global power in a world in which conventional capacities are increasingly disadvantaged by rapidly changing contexts and needs.

COMPETITION AND COOPERATION

While competition can be used to frame US-China biotechnology relationships nowhere will cooperation become more important than with biological weapons. The Biological Weapons Convention entered into force almost fifty years ago.[59] Today, no nation admits to maintaining an offensive biological weapons program but distrust among nations, including the US and China, is at risk of increasing.[60] In 1970 Matt Meselson correctly declared that those who would seek to use biotechnology to cause harm should be considered "hostis humani generis," or enemies of all mankind.[61] It is vitally important that Washington D.C. and Beijing find common ground and creative approaches in cooperating to strengthen opposition to biological weapons at all levels.

Separately, what if the US is unwilling or unable to lead the maturation of biology as a general purpose technology while China succeeds in doing so? In this scenario should we consider a change of posture in which the US adopts a more cooperative "second place" stance? We would expect to experience significant potential leverage by China over the United States. Everything from access to climate-resilient seeds and essential medicines, to next-generation materials and force projection would become increasingly contingent on Beijing.

OTHER TRENDS TO TRACK

Technologies become true when people make them true.[62] Whichever nation learns to fall in love with biotechnology first will have a significant competitive advantage. How do the Chinese people feel about biotechnology and how does that compare to how Americians feel about biotechnology? Paying careful attention to the cultural context, support for, and engagement with biotechnologies will matter most in the long run. Paying careful attention to how such opinions are shaped and sculpted is important.

[59]https://en.wikipedia.org/wiki/Biological_Weapons_Convention
[60]https://www.defense.gov/News/News-Stories/Article/Article/2963280/russia-and-china-falsely-accusing-use-of-biological-weapons-against-russians-sa/
[61]https://www.scientificamerican.com/article/chemical-and-biological-weapons/
[62]https://vimeo.com/204559504?

POLICY RECOMMENDATIONS

Public funding for biotechnology research in the United States is grossly misallocated. We tend to spend most public treasure on the immediate applications of biotechnology.[63] We fail to sustain public investments in the foundational science and tool development needed to generate an evergreen transformation in how we partner with biology to solve problems. The private sector attempts to fill the gap (e.g., Codon, Gen9, Amyris, Zymergen, Gingko) but more often than not fails to mature new tool platforms soon enough to realize commercial success.

Consider how much money the NIH spends, directly and indirectly, supporting researchers building the DNA constructs they need to conduct NIH-sponsored research (over a billion dollars per year). Now ask how much money the NIH spends getting better at building DNA (at most a few percent of the cost to the taxpayer of building DNA). The situation is akin to if computer scientists could only receive funding for working on mobile phone applications that help patients in doctors' offices tomorrow. Proposals to create new compilers, programming languages, and operating systems – all seeking to make the process of solving problems with software, in general, easier – would be rejected. What disease does "making it easier to cure diseases" cure?

To lead in biotechnology in perpetuity the United States needs to smartly spend only a few billion dollars per year. But we must transpose how capital is allocated. Public capital must focus on extraordinarily high leverage and risky foundational research. Private capital should support entrepreneurs who can quickly and reliably translate scaled-solutions to market. The challenge for the USG will be to make such adjustments as needed to support foundational and high-leverage opportunities. For example, the forthcoming report from the National Security Commission on Emerging Biotechnology[64] has an important opportunity to support emerging, and not entrenched, biotechnologies. Here are some examples of high-leverage opportunities:

(1) Resource NIST to create a Bio-Measurement Laboratory (BML). The NIST BML should push the limits of measurement science in biology to establish and promulgate the standards that accelerate scaling of the US bioeconomy and guarantee that as much of the world as possible is operating on America's biotechnology stack. Leading in biometrology and standards setting will advantage all US activities globally, from biotechnology regulation to biosafety and biosecurity policy and beyond.

(2) Re-task DARPA BTO and ARPA-H to focus on the foundational science and technology opportunities and surprises that will fill in biology as a strategic domain (e.g., create and secure a "bionet" unlocking distributed manufacturing resilience). Dramatically dial back the focus on immediate utility to the warfighter and patient, respectively.

[63]The pressures to do so are justified (e.g., cure diseases and make biofuels now) but hinder progress overall.
[64]https://www.biotech.senate.gov/

(3) Repurpose or increase DOE funding to launch and support one or more National Biotechnology Accelerators whose primary mission is to relentlessly improve how researchers practice biotechnology and its underlying workflows (i.e., measuring, modeling, and making with biology). Public treasure gains the highest leverage when taxpayer money supports developing the tools that entrepreneurs later build upon for free.[65] World-leading biotechnology tools are an absolute requirement if the United States is to be the world leader in biotechnology.

(4) Repurpose or increase DOE funding to launch and support one or more Large Language Laboratories (LLLs) whose mission is to guarantee that the United States has the world leading foundation models in biology and biotechnology.

(5) Repurpose or increase DOD, DHS, HHS, and USDA funding to launch and sustain a joint National BioDefense Institute (NBDI) that convenes and supports the nation's best scientists and engineers in leveraging emerging biotechnologies to secure biology. To the greatest extent possible the NBDI should conduct its work in the open and in partnership with industry and international partners.

(6) Akin to GEOINT, task and support the Intelligence Community, DOD, Centers for Disease Control and Prevention (CDC), DHS, and the private sector in launching and sustaining a BIOINT consortium whose mission is to see behind the "molecular curtain" and help win a future free of biological catastrophe.[66]

(7) Increase support to the National Science Foundation for foundational science and engineering research in biology and biotechnology ten-fold. Make sure the support is used for foundational, blue-sky discovery and innovation. Adopt more effective models for allocating research funds.[67]

(8) The relevant Senate and House committees overseeing science and technology should make it obvious that America is "all in" on biotechnology by showcasing the nation's priorities, actions, successes, and opportunities via a central online resource, "bio.gov." This online resource must endure across administrations (e.g., where is ai.gov?).

In 1940 Marc Bloch wrote *Strange Defeat*. The choices we make, or fail to make over the next few years, will determine the architecture of a global biotechnology system. One path leads to multilateral flourishing within a human generation. Another leads to scarcity, stress, and worse.

[65]https://nap.nationalacademies.org/read/24656/chapter/1
[66]https://www.linkedin.com/posts/drew-endy-69ba17_winbywinning-biopartisanship-activity-7261753530116448256-qYzQ
[67]https://www.hypothesisfund.org/

OPENING STATEMENT OF RICHARD ABOULAFIA, MANAGING DIRECTOR, AERODYNAMIC ADVISORY

VICE CHAIR SCHRIVER: Next we will hear from Mr. Richard Aboulafia, who is joining us virtually.

MR. ABOULAFIA: Thank you very much, Commissioner Schriver. To the Commission, thanks very much for giving me the opportunity to testify. My deep regrets and apologies for not being with you in person. Unfortunately, I am here in Seattle at a conference. But it is my privilege to give you a briefing of what I have provided in my testifying paper, and be available for questions.

First of all, it is important to consider China's achievements in aviation in the broader context of history. Since really World War I, no company has successfully -- or I should say World War II, dawn of the jet age just after -- no company or country has joined this industry as a player. Embraer of Brazil managed to start delivering regional jets. It has done very good job of that. But joining the big jet club with Airbus and Boeing, a lot of people have talked about it, a lot of people have tried. No one has succeeded except for China.

The old Soviet Union had kind of a parallel industry that developed starting at around the same time. Predictably enough, of course, like every other consumer product in the old Soviet Union it died as the wall came down.

But China has joined the club. Sometime in the 1970s they started putting considerable state resources into the development of a jetliner industry. Their first attempt was simply taking a Boeing 707 and copying it, and it became the Shanghai Y-10. That went very badly wrong. But then they went down a path of actually creating something a bit more locally produced.

About 15 years ago, they introduced the ARJ21 regional jet, the C909, and about 150 of those have been built, but of course, other people have joined the regional club.

What is new this time is that about a year and a half ago they began deliveries of the C919, a 150-seat proper jetliner that competes with the heart of Airbus and Boeing's product line. They have delivered, I believe, about 14 aircraft, 12 last year. This is a significant achievement for the simple reason that nobody else in the world has done it, and that alone, I think, is very much worth paying attention to and shows the incredible commitment of resources within China, both in terms of educational and technical institutions, the creation of a dedicated jetliner company sponsored by the state-called COMAC, Commercial Aircraft of China.

However, I should say that these perhaps are not the very best jets ever built. The 909, the regional jet, is very much a copy of something that the West built in the 1980s. As soon as they start ramping up their other programs it is not going to survive. But the 919 is a lot closer to its nearest analog, the Airbus A320Neo and the 737MAX. It is a bit heavier. It has not quite got the same range capabilities. But nevertheless, it is close to the capabilities of its Western equivalents.

How did they get there? Well, very simply, lavish resources. Not quite whole-of-nation efforts, but really very significant in terms of just the sheer amount of capital provided to COMAC and to subsidiary organizations. COMAC is, in theory, a standalone commercial unit, but really its parent is AVIC, Aviation Industries of China, multiple divisions thereof, and that is very much a civil-military crossover organization that is also responsible for meeting China's military needs.

So COMAC is kind of a strange entity aimed at commercial markets, with a lot of resources, including some of the resources provided to China's military entities, but nevertheless, in theory at least, it is commercial.

There is one big issue with China's jets, however. Most of the equipment, the systems, and technologies inside the jet, most particularly the engines, are effectively Western products. Some of those are the result of joint ventures between Western technology companies and systems companies and local Chinese producers, with the stated goal, clearly, of copying them. But there are key areas, particularly engines, where that is not the case, where the engines are simply imported, in a box.

This represents a major issue for China moving forward. If they are going to achieve true self-sufficiency they need their own engine industry. Obviously, an aircraft can't get off the ground without engines. They've started working on one, but here the barriers to entry in jet engines are even higher than in the airliner industry. As a matter of fact, there are only two countries in the world, and three companies -- Rolls-Royce of Britain and General Electric and Pratt & Whitney of the U.S. -- that can build a good commercial jet engine, or indeed a commercial engine of any kind. It is going to take many years, and even more resources, to be able to meet them with some kind of equivalent. It is not even guaranteed that they will be able to.

Therefore, just because of engines alone but certainly other key bottlenecks in technologies, the U.S. can govern what China does moving forward in terms of how many it builds, how many aircraft it builds, in terms of development of next-generation aircraft until they get that jet engine industry up and running, and we don't really know when that is.

There are other limits too. For example, establishing a worldwide product support infrastructure is essential for exporting jetliners. That is going to be a very long road.

Another question I addressed in my report is to the extent to which U.S. and Western aircraft companies rely on China. The good news is from the standpoint of actual value-added technologies, really not at all. The bad news is that there are key materials, whether it is rare earth elements or exotic metals, where, yes, China plays a very significant role, and that is something that we need to keep an eye on.

In conclusion, I have got a couple of recommendations. The most important to remember is that historically, in this industry, a one-nation aircraft program doesn't do very well, Britain and France in the 1950s, for example, or even the Netherlands tried. And the Soviet Union is perhaps the best example. Everything was kept in country. The reason that the West's aviation industry is so great, frankly, is because it crosses borders -- people, capital, ideas, technologies all get shared between the U.S., Japan, Canada, South Korea, Germany, France, wherever else, and that is an enormous strength.

So frankly, I believe the best way to compete with China, with its one-nation approach, is to keep our system open, international, and able to leverage the best technological contribution from all of our friends and allies. Thank you.

VICE CHAIR SCHRIVER: Thank you very much.

Next, Mr. Sunny Cheung.

PREPARED STATEMENT OF RICHARD ABOULAFIA, MANAGING DIRECTOR, AERODYNAMIC ADVISORY

Testimony before the U.S.-China Economic and Security Review Commission
Made in China 2025—Who Is Winning?
February 6, 2025

By Richard Aboulafia
Managing Director
AeroDynamic Advisory

I have been an analyst and consultant in the aviation and defense industry since 1988, with extensive coverage of the China market, Western involvement in China aviation, and of China's own aviation industry. My public writings about the industry can be found at www.richardaboulafia.com.

As a Managing Director at AeroDynamic Advisory, a boutique consultancy focused solely on aerospace and defense, I help manage projects for industrial, financial, government and other clients. Our work includes business and corporate strategy, market and technology assessments, and transaction advisory services.

My testimony aims to provide a brief overview and assessment of China's progress in civil aviation. I have followed the Commission's guidance in addressing eight questions:

1) Please evaluate how successfully China met specific aviation goals laid out in its Made in China 2025 policy document and other relevant industrial and technology plans.

This is an industry with extremely high entry barriers. Since World War 2, with the exception of Embraer of Brazil, no company or country has successfully entered the civil jet transport manufacturing sector. And Embraer has yet to enter what can be termed the large jet market; all of its products seat fewer than 120 passengers. Airbus, Boeing, and the other manufacturers who have since exited the industry were created from companies that have existed for over 100 years. The USSR had its own jet industry, of which only an uncertain remnant survives in Russia today.

Therefore, there is no denying what China and Commercial Aircraft Corporation of China (COMAC) have achieved: they have successfully entered this very exclusive industry. China's CAAC regulatory agency certified China's first production jetliner, the ARJ21 (rebranded C909 in November last year), in 2014. This 70/80-seat regional jet is now in full-rate if limited production; about 150 have been delivered; all but three of these have been to Chinese customers. The three export planes have gone to an Indonesian airline that is effectively owned by China.

COMAC's C919 is a more significant achievement. As a 150/170-seat mainline (i.e., for longer routes and not regional ones) jet, it is firmly in Airbus and Boeing territory, and considerably more ambitious and expensive than anything Embraer has developed. The large jetliner "club" now consists of Airbus, Boeing, and COMAC. Therefore, the biggest "headline" Made In China 2025 aviation goal – "Accelerate the development of large aircraft" – has been achieved.

Made In China 2025 includes many other aviation and aerospace goals. Beyond that one big headline objective (development of a large jet), stated goals in the industrial policy[1] include the following:

- Initiate the development of wide-body passenger aircraft in a timely manner
- Encourage international cooperation in the development of heavy-duty helicopters
- Promote the industrialization of trunk liners and regional aircraft, helicopters, unmanned aerial vehicles (UAVs), and general purpose aircraft.
- Achieve breakthroughs in the technologies of high thrust-to-weight ratios and advanced turboprop (turboshaft) engines and turbofan engines with large bypass ratios and establish an independent industrial system for engine development.
- Develop advanced airborne equipment and systems to form an independent and complete aviation product chain.

The first of these might be a translation problem, or merely a nomenclature mistake. Widebody jets are twin aisle models for international routes. For years, China has been studying a C929 (formerly CR929) twin aisle, which I will discuss below. But this was merely a concept when Made In China 2025 was formulated, and it's possible that the term "wide-body" was merely applied to any jet larger than a regional one. Just below that, it uses the term "trunk liners" which is kind of an old fashioned way of referring to any mainline jet;

Other than that, China has made remarkable progress with UAVs. It has made very little progress with heavy helicopters, some limited progress with other helicopters, and relatively little progress with general purpose aircraft (although it has made some interesting acquisitions of Western general aviation companies).

Then there's the last two items, engines and equipment and systems. These will be essential for China to establish itself as an autonomous (or autarkic) aviation power. There has been progress with these, through a mix of joint ventures (JVs) with Western companies and probably with intellectual property theft. But China is a long way from being independent here, particularly with engines, as discussed later in this testimony.

2) What do the capabilities of COMAC's C909 and C919 indicate about how advanced China's aerospace sector is today?

While developing and delivering jets is a noteworthy achievement, there are four problems with COMAC's position in the industry and market. The first is that the C909 can be termed a deeply flawed product. It is massively overweight relative to its competitors.

The table below shows the three first Chinese airliners in the context of their peers. "EIS" refers to entry into service, the date the plane entered, or will enter, commercial revenue service. "Pax" refers to the typical number of passengers the plane transports. "OEW" refers to the aircraft's

[1] https://cset.georgetown.edu/wp-content/uploads/t0432_made_in_china_2025_EN.pdf

operating empty weight. The final column divides weight by passenger, a good way of judging the relative appeal of designs with similar ranges and operating characteristics.

Plane	EIS	PAX	OEW (lbs)	OEW/PAX
Dash 8Q300*	1989	50	26,042	521
ATR72	1989	72	29,983	416
MA60*	2000	60	30,203	503
ERJ170	2011	72	44,423	617
CRJ705	2001	75	47,245	630
E175	2005	78	48,260	619
Fokker 70*	1994	79	49,985	633
C909	2016	78	55,017	705
A320	1988	158	82,078	519
A320Neo	2016	158	97,700	618
C919	2023	158	100,751	638

China's MA60 turboprop – now largely out of production – is considerably heavier on a per-seat basis than its closest competitor, one of many reasons why it failed to sell in more than token numbers (it is also notably unreliable and regarded by some as unsafe). But the C909, a 78-seat regional jet, is disastrously heavier than its closest competitor, Embraer's E175. All of the systems used on the C909 are basically equal to or inferior to those on the E175. The engines are basically the same (General Electric CF34). Therefore, the economic differential between the two jets comes down to weight.

By most accounts, the ARJ21/C909 design and manufacturing system was based on McDonnell Douglas's MD-80 jetliner, which was built in relatively small numbers in China during the 1980s. The MD-80 was a larger 130/150-seat design, which means the Chinese derivative is carrying a lot of the structure and other components needed for a larger jet. As a consequence of this heavy weight, the C909 almost certainly has a relatively high cost per available seat mile (CASM). It is not likely to be competitive at all outside China, and even Chinese airlines will have a hard time operating the type without extensive subsidies.

Considering its weight relative to its closest peer (Airbus's A320neo), the C919 looks better than the C909, and differing seat counts might erase much or all of this difference with the A320neo, although the C919's range capabilities do appear to be somewhat inferior to its Airbus and Boeing competitors. COMAC's own site gives a range of "4,075 to 5,555 kilometers" (2,200–2,999 nautical miles).[2] Airbus's A320neo, according to Airbus, has a range of 3,400 nautical miles.[3]

[2] http://english.comac.cc/products/ca/

[3] https://aircraft.airbus.com/en/aircraft/a320-family/a320neo

But the C919 faces the second problem confronting COMAC airplanes. As I will discuss in the fourth section of my testimony, the overwhelming bulk of the systems and technologies that make the C919 a functioning jetliner either have Western origins or are directly supplied by Western contractors. This is most notably true for the aircraft's engines.

Thus, the C919 is just as dependent on the global aerospace ecosystem as any other jetliner. Any PRC Government aspirations of air transport autarky with this product need to be tempered by this sourcing reality.

The third problem with COMAC's position is that it has no real track record in product support. Airlines depend on extensive networks of aftermarket products and service to keep their jets operating constantly, with thousands of hours of utilization per year. Airlines have razor-thin profit margins, and idle equipment means lost revenue without commensurately lower expenses (i.e., high fixed costs).

As Air Lease Corporation founder Steve Udvar-Hazy put it, "My biggest question as an aircraft lessor investor, is what is the residual value of a C919 10 years from today? I have no idea, because they don't have a global support network."[4] Creating a worldwide product support network that's as elaborate as Airbus and Boeing's will be extremely expensive.

The fourth problem confronting COMAC is that we don't know how the company will perform at volume production. Last year, COMAC delivered ten C919s, and only around 13 have been delivered so far. The ARJ21/C909 maximum production rate has been in the range of two planes per month, or just slightly higher.

Volume production of conforming aircraft (i.e., building the same plane, without any production modifications or corrections) is one of the key skills needed for any jetliner prime contractor. In addition to maintaining quality standards and keeping production line cadence, a manufacturer must manage an extremely complex (and global) supply chain that delivers the strong majority of the value of any aircraft. This is a hard-learned skill.

Last year, Airbus delivered 766 jets. Boeing, at its peak (before the 737MAX problems) delivered 806 jets (in 2018). COMAC aspires to deliver 50 C919s by 2026, and then a steady ramp to 120 per year. There are no guarantees that COMAC will be able to reach these goals in the planned timeframe.

Finally, because the early stages of production in any jetliner program tend to be extremely capital intensive and money-losing, there are no guarantees that funding will be provided. It's safe to say that it will be a very long time before any COMAC jetliner program turns cash-positive on a recurring basis, let alone profitable on a program basis.

3) What policy instruments helped develop China's current capabilities in aviation, especially as regards COMAC's development of the C919?

[4] Victoria Moores, "Straight Talker," Air Transport World, January/February 2025, page 45.

Perhaps the most important aspect of China's aviation industrial policy is that it has been extremely patient. China has attempted to build a national jet for decades, without success. The closest it got for 35 years was the Shanghai Y-10, a Boeing 707 knockoff that was built and flown in prototype form in September 1980. After a very poor flight test, it was cancelled after two prototypes were built.

The dream persisted. In the mid 1980s, one Western observer of China's aviation plans commented:

> Aircraft manufacturing is considered as the 'flower of industry,' reflecting the industrial level of a nation, and the Chinese are determined to reach parity with the West. Achievement of parity is proving to be elusive. The plan first to build small and medium airplanes and then expand to larger and more sophisticated machines is good in principle, but is progressing much more slowly than the Chinese planners had anticipated.[5]

There were several Chinese jet projects in the 1980s and 1990s, as China liberalized and opened up to JVs with Western companies (as opposed to the Y-10, which was not at all cooperative, and merely a stolen copy). The most notable new-start program was the MPC-75, a 75/90-seat regional jet in the ARJ21/C909 class proposed in the late 1980s. This was a cooperative project between China's CATIC and Germany's MBB, now part of Airbus.

Also, China built 35 MD-80s under license to McDonnell Douglas. It also almost built the MD-90, but this was cancelled. In the mid-1990s Airbus, AVIC, and Singapore Technologies worked on the AE-100, a 100-seat jetliner. It went nowhere. The next project was the closely related Airbus/AVIC AE31X, also a 100-seat design that was cancelled in June 1998.

In December 2005 Airbus signed an MoU with China's National Development & Reform Commission (NDRC) to establish an A320 final assembly line (FAL) in China. The first plane rolled off the line in June 2009. This line is still quite active today, building large numbers of A320neos (a direct C919 competitor).

The first reference to what would become the C919 came in 2006 when the PRC announced its 2006-2010 five-year plan. It referred to a "jumbo" jet, but initial drawings indicated something in the 767 class. In February 2007 the PRC State Council declared that China needed a large jetliner, with an anticipated delivery date of 2020. This was later brought forward to 2016.

The C919 received official launch approval, albeit without orders, in May 2008. The same month, COMAC was formed, although initially it was referred to as CACC. COMAC is not part of AVIC, but it is made up of AVIC assets, including the Shanghai Aircraft Manufacturing Factory (SAMF).

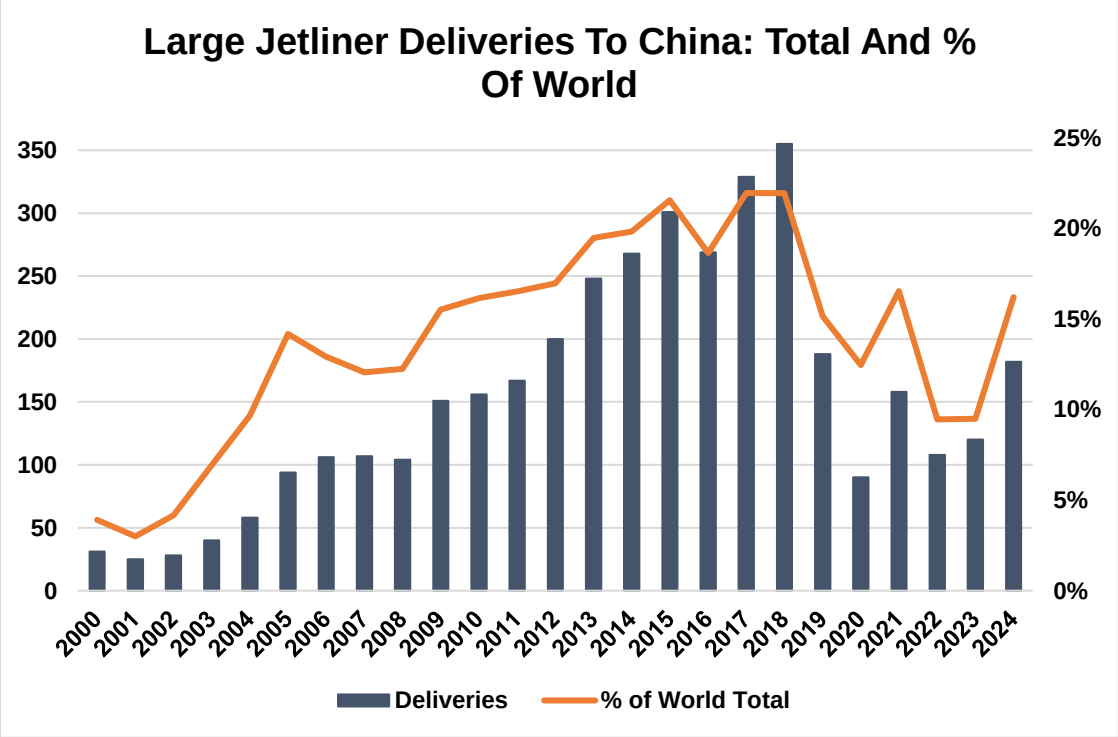
[5] E. E. Bauer, *China Takes Off: Technology Transfer and Modernization*, Seattle: University of Washington Press, 1986, page 290

Beyond the magic ingredients of time and patience, PRC Government policy took multiple forms. There was the direct government support needed to create COMAC as a state-owned enterprise (SOE). Some of this funding came from the NDRC. There was also local government support, particularly from Shanghai, where COMAC is based.

There was also the support provided by the Made in China 2025 industrial policy, which clearly prioritized aviation and aerospace as key sectors. This policy also made it clear that civil and military aviation and aerospace development were intertwined, guaranteeing a higher level of funding and support.

Next, there were government efforts to cultivate COMAC and Chinese industry progress outside of creating the jets themselves. The government established stated requirements for Western aerospace companies to form JVs with Chinese companies, in exchange for China domestic market access (as described later in this testimony).

These JVs mandated technology transfer, also tied to market access. As the chart below indicates, China's market, at its peak, absorbed 22% of the world market for large (120+ seat) jetliner deliveries, making it the largest single export market country by a considerable margin. The PRC Government was able to use the enticement of this large and growing (until 2019) market to entice international manufacturers to agree to aggressive technology and work transfer terms.



Also, the PRC Government has mandated aircraft orders for COMAC jetliners from state-owned Chinese airlines. It should be noted that in the past, there was a resistance by these airlines to purchasing any aircraft made in China. Of the 35 MD-80s built in Shanghai, five had to be re-

exported back to the US because Chinese airlines refused to buy them. These were put into service with TWA.

One outstanding question is whether PRC Government pressure on airlines to buy C919s will be offset by Chinese airlines' ability to buy A320neos from the Tianjin FAL, which is now ramping up to be capable of building over 100 jets per year. In other words, will airlines be able to show support for local industry through a different fleet plan?

Perhaps as a way of dealing with this question, the PRC is mounting a broader "national pride" strategy for the C919. Some reports indicate a marketing plan involving higher ticket prices for a "luxury" flight in a C919. In the opposite direction, one report indicates a marketing strategy revolving around more mileage awarded for flying in a C919, and that C919 flights have been awarded more appealing time slots. Again, since the airlines are government-owned, all of these plans are feasible.

For C919 export sales, if and when they occur, one frequently asked question involves the PRC's Belt and Road Initiative (BRI). Will recipients of BRI loans and aid, particularly for air travel infrastructure, also be pressured or incentivized to purchase C919s? So far, there is no clear indication that this will be the case, but many observers view it as a strong possibility. On the other hand, most BRI aid and loan recipients represent relatively marginal markets for new jetliners, and new C919s would compete against a plentiful supply of inexpensive used Western aircraft.

Finally, there was the indirect and direct government support needed to create the workforce and institutions needed for China's aero industry development. This encompassed everything from testing facilities to university education and training programs to manufacturing infrastructure to various research institutes. This cannot be quantified but is likely to be large and essential to COMAC's successful jetliner market entrance.

4) In areas where China is behind its stated goals, or did not have the same level of success, what does this suggest about the limitations of its approach and potential policy responses in the future? What are the key bottlenecks remaining for Chinese aviation?

This is a broad set of questions, but they are best examined on a collective basis. For China, there are three areas of concern regarding limitations and bottlenecks.

The first limitation concerns the intellectual property (IP) being transferred by international suppliers to their Chinese JV counterparts. The understandable fear of enabling a Chinese competitor is likely keeping these suppliers from bidding their latest and best technology on COMAC jets. IP rights have been a longstanding concern for Western manufacturers in China, but dealing with state-owned companies (and all Chinese aerospace companies are SOEs) makes the problem even worse.

While there's no clear proof that suppliers are offering less than cutting edge technology, it is not possible to imagine a supplier company's board not asking tough questions about work in China. Foreign companies won't have an easy time against the Chinese Government in an IP dispute.

The fact that the C919 looks like an A320 – as built by Airbus in Tianjin – is all the reason Western manufacturers need to maintain a cautious stance regarding technology transfer.

This cautious stance means that in many cases international suppliers are working with China using slightly (or very) dated technology. Added together, these dated technologies add up to a finished jet that is a somewhat less than state-of-the-art product. Even if only a minority of suppliers are being cautious, that's enough to burden a COMAC jet with less capable systems that impair its competitiveness.

Also, China's aircraft designers have had their options limited. They can only source equipment from Western companies that are willing to transfer technology (old or new). They can't just select the best supplier for a particular task. That too contributes to less than state-of-the-art jets.

Since innovation mostly happens at the subsystem level, aircraft designers need to realize an important lesson: national vertical integration is a very bad idea. Jet builders need to be free to select "best-in-class" content for their jet from a wide range of suppliers with no permanent links to the primes.

That is the primary reason why this industry is a global one. Embraer, for example, isn't just a Brazilian export powerhouse. It's also one of Brazil's biggest importers. They survey the world for the best suppliers and build very little in-house.

Engines are the second big limitation for Made In China 2025, and a bottleneck for future technology development. Engines are the weakest link in China's civil aviation plans. Other aircraft systems and technologies, and even complete aircraft, may be difficult to develop, but jet engines are at a completely different level in terms of barriers to entry.

In fact, only three companies, located in two countries (General Electric and RTX/Pratt & Whitney in the US and Rolls-Royce in the UK) build commercial jet engines. France's Safran plays a role as a partner to GE in the CFM JV (which supplies Leap-1C engines for the C919), but otherwise there are no other engine sourcing options. France, the second most important aviation manufacturing country in the world after the US, has no history of building its own commercial jetliner engines.

Russia is not a commercial jet engine supplier option for China. The Soviet Union had a second-rate commercial aero engine industry for domestic applications, but Russia's efforts to revive it have been uncertain and very slow. Only tiny numbers of obsolete models have been manufactured over the last few decades. There are plans for new engines, but international sanctions, massive corruption, and the brain drain of the past few years have likely doomed whatever chances Russia's aero engine industry once had. Besides, Russia's priority is now military systems. Even there, China is working on replacing Russian engines on its home-grown military aircraft.

This is why there is no Chinese engine JV with Western companies. All three Western engine companies refused to transfer any meaningful engine design and production technology. They wanted to protect their proverbial keys to the kingdom.

Therefore, to achieve the desired goal of aviation self-sufficiency, China is now working on its first commercial jet engine. AVIC Commercial Aircraft Engine (ACAE) is designing its CJ-1000A as an alternative to the Leap-1C on the C919. The first of these was scheduled to be built in 2016 but was finally completed in December 2017. Service entry was scheduled for 2020.

Not only did this not happen, but ACAE has been forced to return to the drawing board. The first version of the CJ-1000A was heavily dependent on Western suppliers and contractors.[6] It was apparent to the PRC Government that, as with China's jetliners, China's first attempt at a commercial engine could easily be shut down with Western technology embargoes. ACAE, as a unit of AVIC, is under US Government sanctions as a military end user.

The new CJ-1000A is intended to be completely Chinese. It reportedly made its first observed flight in March 2023.[7] The current plan is for this new, all-Chinese CJ-1000A to be available in 2030, but this will likely prove optimistic.

By several accounts, China is preparing to introduce a new C919 version with purely Chinese systems and the all-Chinese CJ-1000A engines sometime around 2035. This should be achievable. However, both of these issues – JV technology transfer limits and aero engine self-sufficiency limits – speak to the unusual nature of airline economics.

For an airline, capital costs (i.e., buying a jet) are not as important as operating costs (operating that jet, particularly for fuel and maintenance). Airline profit margins tend to be razor-thin. Thus, if an airline competes with another airline using a jet that's, say, 5% less efficient than that competitor's jet, the competitor can out-price and out-profit the airline with the slightly inferior product. This is not the automotive industry or consumer electronics industry, where sticker price and product features matter most. This is an exacting contest of operating costs.

In sum, China may well produce an all-Chinese jet by 2035. But the very idea of a national jet is fundamentally obsolete. Airbus and Boeing jets are global products for a reason – global sourcing guarantees the best product with the best operating economics. An all-Chinese jet might be good for an autarkic future, but as a globally competitive product it will be as disastrous as any all-US or all-French jet would be, and probably to an even greater extent due to China's relative inexperience with aero engine design.

Beyond economics, there is the technical challenge of building a twin aisle, or a widebody jet. To achieve self-sufficiency, China would need these for airline routes connecting the country

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[6] See, for example, Bradley Perrett, "MTU, Avio Will Help China's ACAE Build CJ1000 Turbofan," Aviation Week & Space Technology https://aviationweek.com/mtu-avio-will-help-chinas-acae-build-cj1000-turbofan, accessed February 4, 2025; and https://www.gknaerospace.com/en/newsroom/news-releases/2016/gkn-aerospace-to-supply-engine-shafts-for-cj1000-development-programme/

[7] https://aviationweek.com/air-transport/aircraft-propulsion/chinese-built-turbofan-spotted-wing-avic-y-20-flying-testbed

with the US, Europe, the Mideast, Africa, or Australia. A single aisle model like the C919 simply doesn't have the range.

But here again, entry barriers are very high. Russia, notably, is the only country other than the United States to design and build its own twin aisle jetliner, the Ilyushin Il-86/96 series (itself an economic disaster). European countries only succeeded with twin aisles by pooling their resources through Airbus. No European country succeeded in creating its own.

This is why the C929, COMAC's proposed widebody, was originally the CR929, to be built in conjunction with Russia. But for political reasons (Western sanctions against Russia), and because Russia basically demanded cash for technology without any meaningful level of joint technology development, Russia has been dropped from the program (along with the "R" in the aircraft's designation). China now wants to be the third country in the world to create its own widebody. Or, to put it differently, China now wants to be the second country in the world to create its own successful widebody.

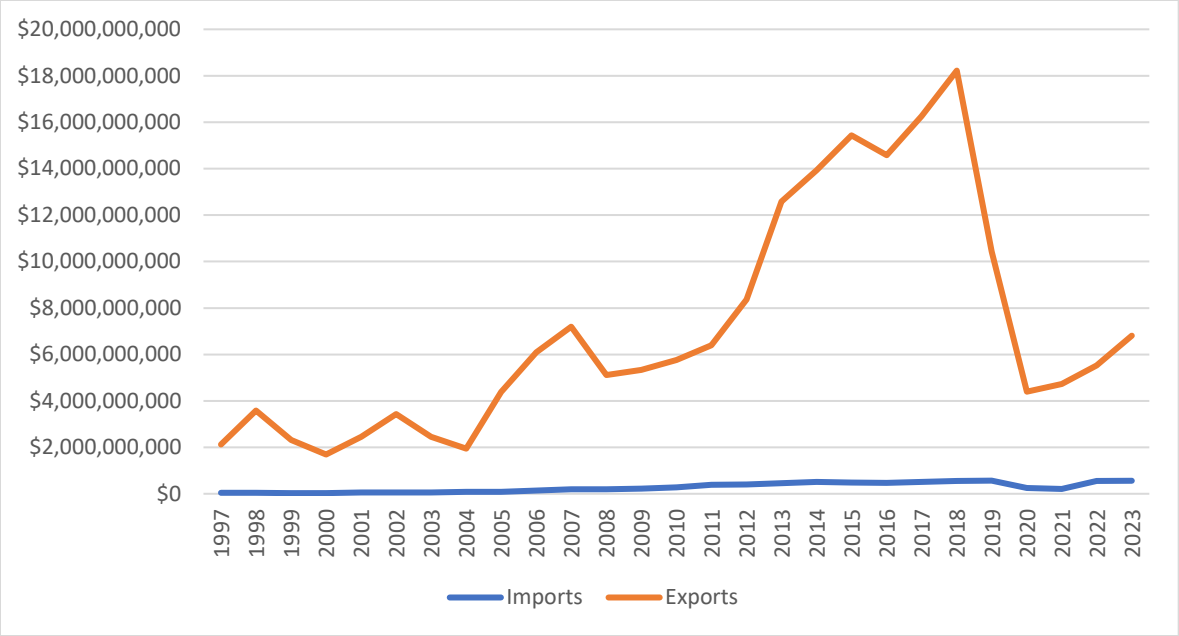
The road to a C929 is likely to be long, hard, and expensive, considerably more than with the C919. And again, without it, China will still be dependent on foreign aviation equipment suppliers.

5) Please describe the extent to which supply chains for aerospace in the United States and third-country markets rely on technology or inputs produced in China.

At the direct aerospace products level, US and Western aerospace companies are not reliant to any meaningful degree on Chinese-manufactured or designed products. At what might be termed the indirect level – raw materials, or technologies that do not have a dedicated aerospace application – there is somewhat greater cause for concern.

Direct inputs are relatively minimal. The US International Trade Commission Dataweb[8] numbers, illustrated in the chart below, clearly shows that there is an enormous China-US aerospace trade deficit in the US's favor. At its peak in 2018, this deficit stood at $18.2 billion in US exports to China to $548 million in aerospace imports from China.

[8] https://dataweb.usitc.gov/



US aerospace exports to China have fallen in recent years due to the 737MAX de-regulation and production stop, slowing Chinese demand growth, political tensions the Covid-19 pandemic and the resultant air travel depression, but are now recovering as some of these factors diminish. But again, US aerospace imports from China never amounted to very much, coming to $553 million in 2023 (the last year available for the ITC database).

According to the US Aerospace Industries Association, US aerospace industry's revenues in 2024 came to $955 billion, of which 47% is for civil aerospace.[9] This means China's contribution comes to roughly 0.05% of total US output, or 0.1% of civil output. None of China's contribution is irreplaceable, and in our conversations with US producers its clear that most, if not all of them have lined up alternative sources of production. These US producers are mindful of tensions, tariff possibilities, and other factors that would lead them towards alternative production sources.

The ITC numbers also indicate that in 2008 Mexico surpassed China for the first time, becoming the eighth largest aircraft parts supplier to the US. Mexico and other emerging producer countries have continued to grow, leaving China behind, and providing exactly the kinds of alternative production sources sought by US producers.

There are international aircraft manufacturers that import Chinese components that aren't captured by the US trade numbers. But this business is quite limited. In fact, Airbus's Tianjin FAL is effectively a mercantilist creation – all the systems and structures for these jets are imported into China from France, the UK, Germany, and other Western producer countries, and are merely assembled in China.

[9] https://www.aia-aerospace.org/news/2024-facts-figures-american-aerospace-and-defense-remains-an-economic-powerhouse/

In fact, one key reason for China's minimal role in the global aerospace supply chain is that the country has always emphasized developing and building finished aircraft, rather than building up an in-country components and systems manufacturing capability. Japan represents an interesting contrast with China. Japan became a world leader in designing and manufacturing equipment for global needs. The country has developed an impressive array of aerospace technologies, primarily due to its long-term partnership with Boeing. But its occasional efforts at being a civil aircraft manufacturer have resulted in half-hearted failures.

China's industrial role in aerospace supply chains around the world is further complicated by the fact that it can play no role whatsoever in defense products for any Western or allied company or country. These Western aviation companies are also mindful that sanctions and other considerations mitigate against any kind of civil aircraft work that can ever be part of a defense product.

For example, a small number of Airbus's A330 jetliners are used as KC-30 military air-to-air refueling tankers. If a Chinese company played a significant role in A330 structures or technologies, that would greatly complicate selling the KC-30 to Western alliance countries. Thus, for this and other reasons, there is very little Chinese content on an A330.

However, US industry does consume significant non-dedicated aerospace content coming from China. These imports are beyond the scope of this testimony. But it does appear that with finished products, the US imports considerable quantities of Chinese printed circuit boards (PCBs).[10] US industry may also depend on China for certain types of high-volume electronic components (basic capacitors, resistors, etc.). Also, with regard to raw materials, US industry does depend on China for rare earth element processing.[11]

6) To what extent has the growth of China's domestic civilian aviation sector led to advancements in its industrial base for military aviation technologies?

As noted above, Made In China 2025 combines civil and military aerospace, with relatively little differentiation. As one geopolitical observer recently put it, "The fact of the matter is, any piece of technology, regardless of its level of sophistication, can be used in military applications - which makes Western export controls flawed by default."[12]

This is particularly true for aerospace. But as a consequence it's very difficult to say when civil developments help in the military realm, and when military development programs contribute to civil ones. For example, much of China's aero engine technology progress has focused on creating Chinese engines for fighter jets and military transports. Thus, China's civil aero engine

[10] https://www.dhs.gov/sites/default/files/2022-02/ICT%20Supply%20Chain%20Report_2.pdf

[11] https://www.areadevelopment.com/logisticsinfrastructure/q4-2024/the-battle-to-break-chinas-rare-earth-supply-chain-dominance.shtml

[12] https://www.geopolitics-insider.com/rus/?ref=geopolitics-insider-newsletter January 26, 2025, accessed January 28, 2025; paywall.

industry will draw from massive investments in military programs. But the CJ-1000A engine development program has also unquestionably helped those military engine development programs.

There are countless other aviation technologies with dual applications. A very short list would include engines, materials, aerodynamics, avionics, flight controls, and power systems.

Then there are the non-technological crossovers. These would include managing aircraft and systems development programs, factory design and organization methods, workforce training and development (and workforces themselves), supply chain management experience, and research and testing facilities and institutions.

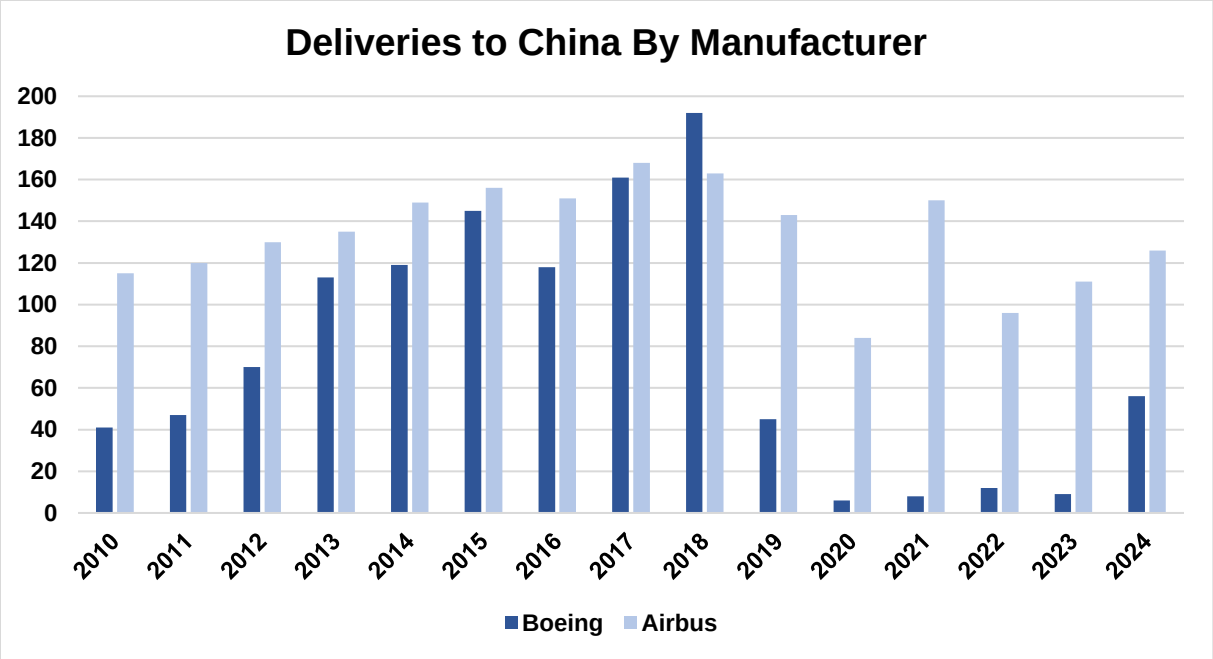
Finally, there are very few aerospace companies worldwide that are not dual civil and military entities in some way. No Chinese companies are not dual entities. China views aerospace manufacturing as an economic and geopolitical whole.

7) What other trends should the Commission be tracking on this topic?

One key trend for the Commission's attention is China's jetliner market, and how open it is, both to Western jetliners and to US-built jets in particular. As noted earlier, this is the largest export market in the world, and a level playing field is essential for the Western jetliner industry, and for Boeing.

So far, deliveries of COMAC jetliners have not been a major factor in this market; after all, a dozen or so C919s out of thousands of Western jets in China hardly registers. But if COMAC starts to ramp up to scores of C919s per year, and possibly over 100 per year, it would control more than half the market on a recurring basis, implying that this was no longer an open market at all.

Another related factor to watch is Boeing's market share. As the chart below indicates, the US company held roughly 50% of China's jetliner market for many years. The MAX grounding, and political factors, basically reduced this share to next to nothing after 2018, but last year saw a rebound, with a roughly 2-1 split in Airbus's favor. Here again, it's essential to keep the China market open, both in general and to both jetliner manufacturers.



Beyond China's open market for jets, in my view the Commission should closely monitor the following:

1. China's progress in displacing Western components, systems, and technologies on its jets with locally designed and built ones.

2. COMAC's progress with the C919 production ramp, and with C919 dispatch reliability rates on par with Western jets (~99%).

3. COMAC's progress in establishing a product support network for its jets outside of China.

4. COMAC's progress in selling its jetliners outside of China.

5. COMAC's progress in designing and creating a twin aisle jetliner (C929, and then C939).

8) What recommendations for legislative action would you make based on the topic of your testimony?

The most important action that the US can take is simple: Keep the Western and allied aerospace industry ecosystem open. China is trying to create a single nation aerospace industry. We've seen this before, in pre-Airbus European countries and, most of all, in the old Soviet Union. China may be bigger, both in terms of resources and as a market, than any of these, but the history of closed industry ecosystems is dismal.

By contrast, the current Western and allied industry ecosystem draws on talent, capital, technology, and innovation from many countries. There are very few barriers to cooperation or market access between the world's leading aerospace producers, particularly the US, Japan, the UK, France, Canada, Germany, Italy, South Korea, and many others. As long as these barriers

stay low, with minimal (if any) tariffs or other trade and cooperation limits, it is not conceivable that this global industry would not be able to out-innovate, and indeed marginalize, a single nation's attempts to do everything in-country.

If China wishes to be part of this global industry, they should be welcomed, and indeed they would likely prosper. If they want to seal their borders and cooperate with nobody outside China, they might be able to replicate the Soviet Union's experience, which was not a happy one.

In my view there are three other initiatives that would support the US aerospace industry's overall competitiveness with China. One is to promote a level playing field for US contractors on China's platforms while preventing China from gaining an unfair advantage in world jetliner markets. The second is take defensive measures against sudden decoupling between the US and China. The third is to ensure that the US jetliner industry remains competitive in world markets.

First, in my view US supplier companies should not be prevented from working with China on COMAC aircraft. In addition to the political ill will this would create, the result would be that China would favor European suppliers, and/or accelerate the creation of a domestic supplier ecosystem. In my view it's better to maintain industrial relations and maintain US leverage over China's industry.

Instead, the US should encourage its supplier companies to work with COMAC, but also be prepared to step in as circumstances dictate. For example, China's MA700 70-seat turboprop transport was effectively halted when the US and Canada embargoed its Pratt & Whitney Canada PW150 turboprop engine[13]. China is searching for alternatives to the Western engine, but again given very high jet engine entry barriers, this will take many years and will likely guarantee a second-rate aircraft.

The legal structure for jetliner decoupling is already in place. COMAC's key parent companies are on the US Military End User (MEU) export list[14], which essentially prohibits technology exports to entities that "represent an unacceptable risk of use in or diversion to a 'military end use'" in China and other countries. The MEU list's application to aerospace exports to China is somewhat opaque, perhaps deliberately. All of China's thousands of Western jets use US technology, with a steady need for spare parts shipped from the US. But clarifying the situation, by putting COMAC directly on the MEU list, would be a very simple move by the US Government.

In a recent article, I spelled out a scenario in which the US Government would want to initiate such a decoupling: as a retaliatory move for a PRC decision to provide Russia with armaments in

[13]Greg Waldron, "MA700 faces bleak future after Ottawa denies export permit for engines," Flight International, https://www.flightglobal.com/aerospace/ma700-faces-bleak-future-after-ottawa-denies-export-permit-for-engines/145605.article, accessed February 4, 2025

[14] https://www.bis.doc.gov/index.php/component/docman/?task=doc_download&gid=2714

its war with Ukraine.[15] As discussed in the section above, it's imperative that China keep its market open to Airbus and Boeing (to a roughly equal degree), even if there is an inevitable degree of favoritism for COMAC products. If China decides to close its airline market to the West or to Boeing, this retaliatory decoupling might be an option.

Second, the US Government should help industry hedge against a cutoff of rare earth elements and other key materials needed for aircraft manufacturing. This could take the form of creating or enhancing strategic stockpiles of these materials, or by establishing alternative sources of supply. Gallium would lead this list, followed by refined Magnesium, Tungsten, and various rare earth elements.

Third, the best protection for US industry against COMAC is to keep innovation flowing. COMAC's products are all "me-too" jets, effectively replicating, and not innovating. If the C929 goes ahead, the best-case scenario is that it will be a 787 equivalent. If the C939 goes ahead, it will be a 777 equivalent.

Therefore, supporting new high-risk/high-reward civil aviation technologies – particularly new airframe concepts and propulsion architectures – would be a positive step. This could be done through a combination of NASA and other agency technology development contracts and Department of Defense military crossover programs. Again, per the recommendation at the top of this section, this new aerospace technology cultivation should be done in full partnership with the US's international allies and friends.

[15] Richard Aboulafia, "If China Arms Russia, the U.S. Should Kill China's Aircraft Industry" Foreign Policy, https://foreignpolicy.com/2023/03/20/china-russia-aircraft-comac-xi-putin/; accessed February 3, 2025; paywall

OPENING STATEMENT OF SUNNY CHEUNG, FELLOW FOR CHINA STUDIES, JAMESTOWN FOUNDATION

MR. CHEUNG: Co-Chairs, Commissioners, thank you for the opportunity to testify.

AI isn't just about large language model. It is future, lies in the physical world. Nvidia CEO Jensen Huang has recently said that ChatGPT moment for robotics is just around the corner, and Tesla has always predicted that humanoid robotics will surpass the values of cars in the foreseeable future.

And this brings me to Made in China, MIC, 2025 scheme. Beijing grand strategy to formulate high-tech industry, although the name might have faded, the vision remains very much alive. And China is pursuing automation not just through enhance manufacturing but to reshape economic power, labor, and military capability.

The Chinese government, at both local and national levels, has invested heavily in robotics for industrial plans and MCF, military-civil fusion fundings. China's goal is clear -- to dominate the hardware, software, and supply chains, a full, aggressive, state-subsidized investment and acquisition. China is not just advancing its domestic industry but also expanding their influence globally.

There are four piers of Chinese robotics and automation expansion. Firstly, industrial domination. China has built the world's largest robotics manufacturing ecosystem. It is now leading in the industrial robotic production of rare earth refining, which is critical for actuators and motors, and space-subsidized robotics clusters. Today, it supplies over half of the world's new industrial robots, rapidly replacing foreign suppliers with domestic alternatives.

Second, humanoid robotics. While Tesla's Optimus prototype is famous, it is still developing. China, however, Unitree G1 model has already demonstrated superior mobility, at only $15,000, way cheaper than the Western alternatives, making mass production more viable.

China's focus on low-cost, scalable robotics accelerates its advantage in commercial deployment.

Thirdly, robotics dog. China is rapidly advancing AI-integrated robotic mobility. Unitree's B2-W robotic dog is now outperforming Boston Dynamics' robotic dog in speed, agility, and AI control, signaling China's growing ability and capability in next-generation robotic movement and autonomy.

Fourth, China is integrating AI-driven drones and robotic combat systems into its military strategy. Its Rainbow Cai Hong and Wing Loong Yilong UAV are widely used by PLA and exported to the Middle East and Africa, disrupting Western security interests. These drones have already been deployed in combat zones like Libya, proving their effectiveness in modern warfare. Meanwhile, let's not forget, DJI already commands over 90 percent of the global market in consumer drones, expanding Chinese influence in both civilian and defense military UAV systems.

That being said, despite all the advancements, China still relies on foreign supplies for some of the critical components to build robots, such as AI chips, high-end actuators, robotic operating systems, and this kind of reliance on foreign components represents an opportunity for the U.S. and its allies to contain China's progress by tightening export controls on advanced materials and manufacturing tools.

China has yet to fully replace Japan and Germany's precision motor and harmonic drives, key components for high-precision robotics. This dependency gives the U.S. and its allies leverage to potentially delay and limit Chinese innovation process.

And here are my recommendations for the U.S. policymakers.

Firstly, I think the U.S. government should establish a dedicated task force or commission to examine critical components essential for robotic development, identifying domestic alternatives for actuators, sensors, AI processors, and implement chips at style policy to secure and strengthen U.S. robotic supply chain.

Second, the U.S. government should also restrict Chinese access to key robotic components, and by tightening export regulations on this component, we can potentially slow down the Chinese ability to advance in high-end automation.

Thirdly, the U.S. should deepen collaboration with Japan, Germany, and other relevant European countries in order to counterbalance Chinese dominance in robotic manufacturing and innovation. The U.S. should also establish joint R&D programs with these allies to ensure that the U.S. has secure access to vital robotic components.

Lastly, the U.S. should accelerate the development of AI-driven military automation, focusing on autonomous UAV defense, robotic inventory support, and AI-coordinated battlefield cooperation.

To conclude, this is more than a technological race. This is a battle for economic and military power. China is moving aggressively, and China has already met many of the objectives it set a decade ago under the MIC, Made in China 2025 grand strategy. However, this does not mean the U.S. has lost. In fact, China has not yet achieved full dominance in the supply chain, and we see some vulnerabilities. And then China has not realized the full potential of robotics AI yet. That is why the U.S. and its allies must act now to maintain leadership in robotics and AI, ensuring this technology aligns with the values of the U.S. and interests. And the stakes could be higher. Now is the time to act.

Thank you, Commissioners, and I look forward to your questions.

PREPARED STATEMENT OF SUNNY CHEUNG, FELLOW FOR CHINA STUDIES, JAMESTOWN FOUNDATION

Testimony Before the U.S.-China Economic and Security Review Commission's hearing
"Made in China 2025—Who Is Winning?"

Sunny Cheung

Fellow, China Studies

The Jamestown Foundation

February 6, 2025

Executive Summary

- **China's Robotics and AI Expansion**
  Under the "Made in China 2025" strategy, China has become a dominant force in AI-driven robotics and autonomous technologies, leveraging state-led investment and supply chain consolidation. It leads in industrial robotics, humanoid robots, UAVs, and UUVs, with companies advancing cost-effective automation. However, China remains reliant on foreign suppliers for critical robotics components, including high-performance AI chips, torque sensors, harmonic drives, and lightweight engineering materials such as carbon fiber and PEEK. Despite this, China is aggressively localizing production and expanding its presence in global robotics markets.
- **Military AI and Autonomous Warfare**
  The PLA is integrating AI into combat operations, developing autonomous decision-making systems, AI-powered drone swarms, robotic infantry, and UUVs for naval warfare. These technologies enable faster battlefield coordination and reduce reliance on human oversight, potentially giving China a tactical advantage in high-speed conflicts. However, the PLA's centralized command structure may slow the transition to fully autonomous warfare.
- **Challenges in China's Robotics Sector**
  Despite its rapid progress, China's robotics industry faces structural weaknesses, including dependency on foreign high-end actuators, AI processors, and industrial automation components. The high cost of lightweight materials limits efficiency improvements in humanoid and industrial robots. Currently, most of China's industrial robots are used for basic manufacturing tasks, with limited AI-driven intelligence, causing more time to automate its key industries.
- **U.S. Strategic Response**
  The U.S. must strengthen domestic AI and robotics leadership by investing in next-generation technologies and reforming military procurement to prioritize AI-integrated warfare. Targeted export controls should limit China's access to critical AI chips, robotic actuators, and navigation sensors. Strategic cooperation with allies such as Japan, Germany, and South Korea is essential to securing key supply chains and preventing technology transfers that could enhance China's autonomous military capabilities.
- **AI-Integrated Defense and OSINT Expansion**
  To counter China's advancements, the U.S. should expand research and deployment of AI-driven combat systems, including swarm drone countermeasures, autonomous UAVs, and AI-enhanced decision-making tools. Establishing a dedicated OSINT agency will be critical to tracking China's technological developments, industrial policies, and supply chain vulnerabilities, ensuring long-term strategic advantages.

I. Overview[1]

Co-Chairs: Vice Chair Randall Schriver and Commissioner Michael Kuiken - Thank you for the opportunity to testify today on Made in China 2025. My testimony will focus on one of the most critical objectives within this industrial strategy—advancing robotics and autonomous technologies. I will provide an overview of China's strategic approach, key industry players, and the broader economic and geopolitical ramifications of its rapid advancements in these sectors.

"Made in China 2025" (MIC 2025) was introduced in 2015 as China's strategic industrial policy aimed at transforming the nation from a manufacturing powerhouse known for low-cost labor into a global leader in high-tech industries. MIC 2025 identified ten key sectors for targeted development, including robotics, high-end CNC (computer numerical control) machine tools, AI, new-energy vehicles, aerospace, and biopharmaceuticals. The plan emphasized technological self-sufficiency, innovation-driven development, and industrial upgrading, reducing reliance on foreign suppliers, particularly in critical technologies like semiconductors, automation, and artificial intelligence.

Although China officially downplayed MIC 2025 in public discourse after facing strong backlash from the United States and other Western countries—who viewed it as an aggressive industrial strategy threatening global competition—the plan's objectives never disappeared. Instead, they were integrated into a broader range of policies and state-led initiatives that continued to receive extensive financial and political support. Over the past decade, China has implemented massive subsidies, state-backed investment funds, and regional development policies to accelerate the growth of strategic industries, particularly robotics and automation, as part of a broader push to enhance national technological sovereignty.

Robotics has been a major focus within this framework, with the MIC 2025 blueprint outlining specific goals to advance industrial robots, special-purpose robots, and service robots.[2] Industrial robots are designed for the manufacturing sector and include multi-joint mechanical arms and multi-degree-of-freedom robots that automate repetitive, monotonous tasks such as welding, material handling, packaging, painting, cutting, and operations in clean rooms. Service robots provide essential services to humans in unstructured environments and encompass domestic robots, medical service robots, and public service robots that operate in agriculture, finance, logistics, and education. Special-purpose robots are developed to perform in hazardous environments and under unique conditions, including military applications, extreme operations, and emergency rescue missions. This categorization has allowed for targeted policy measures and industry-specific support, leading to remarkable growth across all three segments.[3] [4]The plan

[1] The opinions and conclusions expressed in this testimony are the author's alone and should not be interpreted as representing those of The Jamestown Foundation or any of the sponsors of its research.

[2] "Made in China 2025: Promoting Robotics Development" [《中国制造 2025》解读之：推动机器人发展], PRC State Council, 2016, at https://archive.ph/TWqyH#selection-325.9-325.30

[3] Ibid.

[4] "State Council Issues 'Made in China 2025' Outlining Nine Strategic Tasks and Priorities" [国务院印发《中国制造 2025》明确 9 项战略任务和重点], HuanQiu, 2015, at https://finance.huanqiu.com/article/9CaKrnJLa0y

called for breakthroughs in key components such as high-precision servo motors, reducers, sensors, and intelligent control systems, recognizing that reliance on foreign technology in these critical areas hindered China's ability to dominate the global market.

Building on MIC 2025, China reinforced its commitment to robotics with three major national plans in 2021. The 14th Five-Year Plan (2021-2025) (十四五规划) prioritized robotics and automation as key drivers of industrial transformation.[5] In April 2021, the "14th Five-Year Plan for Intelligent Manufacturing Development" (《"十四五"智能制造发展规划》) outlined R&D priorities for intelligent welding robots, smart mobile robots, and semiconductor (cleanroom) robots.[6] By December, the "14th Five-Year Plan for Robotics Industry Development" (《"十四五"机器人产业发展规划》) set a clear goal for China to become a global leader in robotics innovation, high-end manufacturing, and integrated applications by 2025, targeting breakthroughs in core technologies and high-end products while ensuring key components match international standards. The industry is projected to maintain an annual revenue growth rate of over 20% during this period.[7]

Further strengthening its robotics strategy, the 2023 "Robotics+ Application Action Plan" (《机器人+"应用行动实施方案》) aimed to boost robotics density in manufacturing and expand their use in healthcare, logistics, education, and household services.[8] On the other hand, the 2023 "Humanoid Robotics Innovation Development Guidelines" (《人形机器人创新发展指导意见》) emphasized advancements in high-torque density servo motors, intelligent motion planning, bionic perception, and cognitive AI—essential for developing humanoid robots.[9] In 2024, the "Guiding Opinions on Promoting the Innovative Development of Future Industries" (《关于推动未来产业创新发展的实施意见》) further reinforced this focus, detailing key breakthroughs in servo motors, dynamic motion control, bionic perception, cognitive systems, dexterous robotic hands, and electronic skin technology[10].

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[5] "Outline of the 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through the Year 2035" [《中华人民共和国国民经济和社会发展第十四个五年规划和 2035 年远景目标纲要》], PRC State Council, 2021, at https://www.gov.cn/xinwen/2021-03/13/content_5592681.htm

[6] "14th Five-Year Plan for Intelligent Manufacturing Development" [《"十四五"智能制造发展规划》], PRC State Council, 2021, at https://www.gov.cn/zhengce/zhengceku/2021-12/28/content_5664996.htm

[7] "14th Five-Year Plan for the Development of the Robotics Industry" [《"十四五"机器人产业发展规划》], Ministry of Industry and Information Technology of the People's Republic of China, 2021, at https://www.gov.cn/zhengce/zhengceku/2021-12/28/content_5664988.htm

[8] "Robot+ Application Action Plan" [《"机器人+"应用行动实施方案》], Ministry of Industry and Information Technology of the People's Republic of China, 2023, at https://www.gov.cn/zhengce/zhengceku/2023-01/19/content_5738112.htm

[9] "Guiding Opinions on Innovative Development of Humanoid Robots" [《人形机器人创新发展指导意见》], Ministry of Industry and Information Technology of the People's Republic of China, 2023, at https://www.gov.cn/zhengce/zhengceku/202311/content_6913398.htm

[10] "Implementation Opinions on Promoting Innovative Development of Future Industries" [《关于推动未来产业创新发展的实施意见》], Ministry of Industry and Information Technology of the People's Republic of China, 2024, at https://www.gov.cn/zhengce/zhengceku/202401/content_6929021.htm

China's approach to achieving these goals has been multifaceted. The government provided direct financial support through subsidies and tax incentives, making it easier for companies to invest in robotics research and development. Provincial and municipal governments also introduced targeted programs to build local robotics clusters, offering grants and preferential policies to incentivize both state-owned enterprises and private firms to accelerate innovation. As a result, China has not only emerged as the world's largest market for industrial robots but also significantly enhanced its domestic manufacturing capabilities. In 2022, China accounted for 52 percent of all industrial robot installations worldwide, a dramatic increase from just 14 percent a decade earlier.[11]

China's regional governments have also actively supported the robotics industry through localized initiatives. For example, Jiangsu province aims to establish a robotics industry chain worth over 2,000 billion RMB by 2025, while Shanghai is creating a National Humanoid Robotics Innovation Center to drive advancements in smart manufacturing and automation. Similarly, provinces like Zhejiang, Shandong, Chongqing, and Anhui have rolled out targeted robotics action plans, each designed to promote the commercialization and mass production of advanced robots across different sectors.[12]

The results of these sustained efforts are evident in the rapid rise of leading Chinese robotics companies such as UBTech, Fourier Intelligence, Unitree Robotics, and major tech giants like Xiaomi and XPeng, which have expanded into humanoid robotics development. These companies are increasingly competitive in global markets, not just as adopters of automation but as innovators producing cutting-edge robotic systems with intelligent AI integration.

II. Supply Chain and Key Components for Humanoid Robots

Key Technological Modules of Humanoid Robots[13]

Module	Key Components
Environmental Perception Module	Various Sensors, LiDAR, Ultrasonic Sensors, 3D Vision Cameras, Infrared Sensors
AI Chipset Module	AI Processors, Neural Network Accelerators, Memory & Storage, Machine Learning Optimization
Motion Control Module	Controllers, Actuation Systems, High-Precision Reducers, Robotic Joints, Balance Control Systems
Operating System Module	Real-Time OS, Human-Robot Interaction, AI Behavior Adaptation, Cloud Integration

[11] World Robotics 2023 – Extended Version" [World Robotics 2023 – Extended Version], International Federation of Robotics (IFR), 2023, at https://ifr.org/img/worldrobotics/2023_WR_extended_version.pdf
[12] See Appendix
[13] Author's analysis

Actuators and Robotic Joints

Actuators serve as the fundamental drivers of robotic movement, effectively acting as the "muscles" of humanoid robots and drones. These components enable robots to execute precise, controlled movements essential for tasks such as walking, grasping objects, and navigating complex environments.[14]
Precision reducers serve as the intermediate mechanism between power sources and actuators, allowing for controlled speed matching and torque transmission. In industrial robotics, nearly every joint is equipped with a reducer to achieve precise movement control. The two primary types of reducers used in industrial robots are RV reducers (RV 减速器) and harmonic reducers (谐波减速器), each hold around 40% of the market share in the global market.[15] RV reducers are typically applied to the base and large arms of industrial robots due to their strength and load-bearing capabilities, whereas harmonic reducers are preferred for smaller arms, wrists, and hands due to their lightweight and high precision.[16]

The harmonic drive gear (谐波减速器), an advanced gear system allows for high-precision lightweight motion with minimal backlash, , has been an ideal solution for humanoid robots which requires smooth articulation. A prime example of harmonic reducer application is Tesla's Optimus humanoid robot, which employs 14 harmonic reducers across various joints, ensuring precise and fluid motion.[17] Harmonic drives operate using a wave generator, a flexible gear (flexspline), and a rigid gear (rigid spline). By leveraging controlled elastic deformation, these gears ensure smooth, precise movement while maintaining a compact form factor.[18]

Japan’s Harmonic Drive Systems has held an overwhelming market share, holding a staggering 80% of the international market. However, Chinese firms such as Suzhou Green Harmonic (绿的谐波) have emerged as strong competitors, now capturing approximately 26% of the domestic market, largely due to policy-driven investments aimed at achieving self-sufficiency.[19] Other key Chinese manufacturers such as ZhongDa Leader (中大力德) and Hubei Kofon Intelligent Transmission (科峰智能) are actively expanding their presence in the planetary and RV reducer

[14] "Three Methods for Calculating the Transmission Ratio of Planetary Gear Mechanisms and Their Comparison"[《三种计算行星齿轮机构传动比的方法及其比较》], Xiao Min (肖敏), Zeng Xiaolan (曾小兰), Journal of Mechanical Engineers [《机械工程师》], No. 11, 2006.
[15] Other types such as precision planetary reducers and cycloidal reducers accounting for the remaining 20%
[16] Research Status of Precision Reducers for Industrial Robots" [《工业机器人用精密减速器研究现状》], Lin Jianghai (林江海), Modern Manufacturing Technology and Equipment [《现代制造技术与装备》], 2024, at https://archive.ph/861Qa#selection-359.21-359.39.
[17] "Another Look at the Tesla Robot: The Planetary Roller Screw" [Another Look at the Tesla Robot: The Planetary Roller Screw], KGG Robots, 2023, at https://www.kggfa.com/news/another-look-at-the-tesla-robot-the-planetary-roller-screw/
[18] Ibid.
[19] Jamestown’s analysis based on MIR Databank

markets.[20] [21]Although China still lags behind Japan in terms of overall precision and durability, aggressive government support and investment in R&D have incrementally narrowed the technological gap.

Ball Screws and Their Role in Robotics

Ball screws (丝杠) are a core component of robotic linear joints, playing a crucial role in converting rotary motion into linear displacement. Ball screws are classified into three types based on friction characteristics: sliding screws (滑动丝杠), rolling screws (滚动丝杠), and hydrostatic screws (静压丝杠). Among these, rolling ball screws are the most widely used in industrial automation, with two major subtypes: ball screws (滚珠丝杠) and planetary roller screws (行星滚柱丝杠).[22]

In the humanoid robotics sector, ball screws are primarily used in linear joints, including robotic arms and legs. Planetary roller screws and sliding screws are preferred for high-load applications such as robot arms and thighs due to their high precision, durability, and impact resistance. Compared to traditional ball screws, planetary roller screws offer superior precision, speed, and lifespan, making them a preferred choice for high-performance humanoid robots.[23]

China's high-end ball screw market remains largely dominated by Japanese and European manufacturers, with key players including THK (Japan), NSK (Japan), Rollvis (Switzerland), GSA (Switzerland), Ewellix (Sweden), and Rexroth (Germany). According to industry reports, Japanese and European manufacturers controlled approximately 90% of China's planetary roller screw market in 2022, underscoring the significant technological gap between domestic and international firms.[24]

The primary barriers to China’s advancement in precision ball screws lie in manufacturing expertise, advanced machinery, and material processing. High-precision ball screw production involves dozens of machining steps, including turning, heat treatment, grinding, and surface finishing, requiring exceptional technical precision at tolerances as fine as P1-level accuracy.

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[20] "Company Overview: Ningbo ZhongDa Leader Intelligent Transmission Co., Ltd." [Company Overview: 宁波中大力德智能传动股份有限公司], Ningbo ZhongDa Leader Intelligent Transmission Co., Ltd., at https://f10.eastmoney.com/CompanySurvey/Index?code=SZ002896&type=soft.

[21] "Company Overview: Hubei Kofon Intelligent Transmission Co., Ltd." [Company Overview: 湖北科峰智能传动股份有限公司], Hubei Kofon Intelligent Transmission Co., Ltd., at https://www.kofon.com.cn.

[22] Modeling, Simulation, and Experimental Research on Electro-Mechanical Braking" [《电子机械制动的建模、仿真和实验研究》], "Metal Cutting Machine Tools (3rd Edition)" [《金属切削机床（第 3 版）》], 2022.

[23] "Discussion on the Plastic Forming of Planetary Roller Screw Mechanism" [《行星滚柱丝杠副滚柱塑性成形的探讨》], Zhang Dawei (张大伟) and Zhao Shengdun (赵升吨), 2015.

[24] Robot Ball Screws: Focus on Product Iteration and Domestic Substitution, with Processing Equipment and Cutting Tools Benefiting Simultaneously" [《机器人丝杠，关注产品迭代和国产化，加工设备和刀具同步受益》], Shenwan Hongyuan Research [申万宏源研究], 2022

Additionally, high-precision manufacturing depends on skilled labor and specialized equipment, which has historically been dominated by overseas manufacturers.[25]

Sensors and Perception Systems

Robotic intelligence depends on sensors to interpret both external and internal data, enabling autonomous decision-making and adaptability. Sensors are categorized into internal and external types. Internal sensors measure the robot's motion state, including kinematic and force data, allowing precise control over movement. External sensors detect environmental conditions, such as vision and force interactions, enabling robots to interact with their surroundings. Different robotic applications require varying sensor types. Industrial robots rely on positioning, force, touch, and vision sensors for assembly and logistics operations. Specialized robots may integrate advanced cameras, microphones, temperature sensors, and light sensors to adapt to diverse environments and user needs.[26] As robotic applications evolve, the demand for advanced sensor integration is increasing, enhancing adaptability and operational intelligence.

Torque sensors are crucial in robotics, converting mechanical force into electrical signals for precise force measurement. Based on different working principles, torque sensors are categorized into strain gauge, inductive, capacitive, photoelectric, and electromagnetic sensors.[27] Among these, strain gauge sensors dominate the market due to their maturity and reliability, functioning by detecting strain-induced resistance changes to produce measurable electrical signals. According to IMARC Group, the global torque sensor market reached $8.2 billion in 2022 and is projected to grow to $13.7 billion by 2028, reflecting a 9.2% CAGR. Leading global manufacturers include HBM (Germany), Vishay (USA), Mettler Toledo (USA), and Flintec (Sweden).[28]

Six-axis force sensors provide multi-dimensional force feedback, allowing robots to perform intricate tasks requiring precise force perception. They are essential in robotic automation, automotive testing, medical technology, aerospace, and scientific research. Due to their complexity, these sensors have high technical barriers, making large-scale production challenging. ATI (USA) dominates the global six-axis force sensor market, maintaining a leadership position in robotic force measurement solutions. In China, companies such as Kunwei Technology (坤维科技), Yuli Instruments (宇立仪器), Xinjingcheng (鑫精诚) and others are advancing in collaborative robotics applications.[29] [30]However, domestic manufacturers still lag in

[25] Ibid.
[26] Shenzhen Xinjingcheng Technology Co., Ltd. Official Website" [深圳市鑫精诚科技有限公司官方网站], at https://www.xjc18.com.
[27] Torque Sensor Market Report 2024-2032" [Torque Sensor Market Report], IMARC Group, 2024, at https://www.imarcgroup.com/torque-sensor-market.
[28] Ibid.
[29] "Kunwei Technology Official Website" [《坤维科技官方网站》], Kunwei Technology (坤维科技), at https://www.kunweitech.com.
[30] "Yuli Instruments Official Website" [《宇立仪器官方网站》], Yuli Instruments (宇立仪器), at https://www.srisensor.com.cn.

sensitivity, overload resistance, and signal interference reduction. Continued R&D investments are helping to close this gap, improving sensor performance and reliability.

Six-axis force sensors are among the most expensive components in humanoid robots. GG Robotics estimates that force sensors used in robotic joints and end-effectors contribute up to 15% of total component costs.[31] Their complexity and precision make large-scale production difficult. Despite high costs, the six-axis force sensor market remains relatively small and has yet to reach full commercialization. However, growing industry participation and cost reduction efforts are accelerating adoption. Chinese manufacturers are focusing on product validation and industrial applications, paving the way for mass production and lower costs in the near future.

Motors

Coreless Motors (空心杯电机)
Coreless motors, a type of servo control motor, are widely used in robotics due to their lightweight and high efficiency. These motors are valued for their fast response, low inertia, and smooth motion control, making them particularly useful for humanoid robots where precision movement is essential.

Currently, the global coreless motor market is dominated by Maxon (Switzerland), Faulhaber (Germany), and Portescap (Switzerland), which lead in performance and reliability. Chinese manufacturers, such as Mingzhi Electric (鸣志电器), have made advancements, gradually closing the technological gap. Domestic firms are leveraging cost advantages and increasing R&D investment to compete with leading global players, with further market expansion expected as downstream applications grow.[32]

Frameless Torque Motors (无框力矩电机)
Frameless torque motors, a type of servo motor, consist solely of a rotor and a stator, without an outer housing. This unique structure allows for flexible integration into robotic systems, making them ideal for collaborative robots (协作机器人) and industrial automation applications. Their compact size, lightweight construction, and adaptability to various configurations align with the increasing trend of integrated robotic drive systems.

Major global manufacturers of frameless torque motors include Kollmorgen (USA), TQ RoboDrive (Germany), and Moog (USA). In China, Buke Co. q are emerging leaders in this field. While domestic products are becoming increasingly competitive, international brands still dominate applications requiring extreme precision, such as surgical robots. However, in collaborative robotics, the adoption of Chinese-made frameless torque motors has been steadily increasing due to their cost advantages.[33]

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[31] "Six-Axis Force Sensors: A Key Component Track for Humanoid Robots, Leading Companies Strengthen Their Dominance" [《六维力传感器：人形机器人零部件关键赛道，龙头强者恒强》], Baijiahao, 2023, at https://baijiahao.baidu.com/s?id=1787142519965387411

[32] "Analysis of Coreless Motor Companies and Overview of Technical Barriers" [《空心杯电机企业梳理、技术壁垒一览》], Motor Alliance [电机联盟], January 27, 2025.

[33] Ibid.

Rare Earth Permanent Magnets

High-performance neodymium-iron-boron (NdFeB) (高性能钕铁硼永磁材料) magnets are crucial in servo motors, enabling compact, efficient designs with strong magnetic properties. These magnets are essential in humanoid robotics, where high torque density and energy efficiency are key.[34] For example, based on estimation, Tesla's Optimus robot uses 28 frameless torque motors and 34 coreless motors, requiring about 4.5 kg of high-performance NdFeB per unit.[35] If the industry scales to 10 million units, demand for these magnets would rise by 45,000 tons, fueling significant sector growth.

Recognizing their strategic importance, China has enacted policies to accelerate NdFeB development. The 2016 "New Materials Industry Development Guide" (《新材料产业发展指南》), issued by MIIT, NDRC, MOST, and the Ministry of Finance, classified high-performance NdFeB as a "key strategic material," promoting energy-efficient rare earth magnet motors.[36] In 2021, MIIT reinforced this priority by including them in the "Key New Materials First Batch Application Demonstration Guide" (《重点新材料首批次应用示范指导目录（2021 年版）》), supporting commercialization and scaling.[37]

China leads global sintered NdFeB magnet production, exceeding 230,000 tons in 2022, yet only 64,000 tons (less than 30%) met high-performance standards.[38] Leading Chinese producers are expanding capacity. JL MAG (金力永磁), a global leader, had 23,000 tons of capacity as of Q1 2024 and plans to reach 40,000 tons by 2025, including advanced magnet assembly lines. Ningbo Yunsheng (宁波韵升), another top producer, had 21,000 tons of capacity by mid-2024 and is developing a 15,000-ton intelligent manufacturing project in Baotou.[39] With strong policy support and continued R&D investment, demand for high-performance NdFeB magnets is set to grow rapidly, especially in robotics and automation. Advances in metallurgy, sintering, and supply chain integration will further strengthen China's leadership in rare earth magnet production.

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[34] "Jinli Permanent Magnet Research Report: Leading High-Performance NdFeB Magnetic Material Supplier with Strong Long-Term Growth Potential" [《金力永磁研究报告：高性能钕铁硼磁材龙头，远期成长动能充足》], 2024.

[35] "Will Tesla's Humanoid Robot Core Materials Change?" [《特斯拉人形机器人核心材料或生变？》], Robotics Lecture Hall [机器人大讲堂], Baijiahao, 2024, at https://baijiahao.baidu.com/s?id=1797672200781782294.

[36] "New Materials Industry Development Guide" [《新材料产业发展指南》], Ministry of Industry and Information Technology, National Development and Reform Commission, Ministry of Science and Technology, Ministry of Finance, December 30, 2016, at https://app.www.gov.cn/govdata/gov/201701/23/397855/article.html

[37] "Guiding Catalog for the First Batch Application Demonstration of Key New Materials (2021 Edition)" [《重点新材料首批次应用示范指导目录（2021 年版）》], Ministry of Industry and Information Technology of the People's Republic of China, December 2021, at https://gxt.fujian.gov.cn/zwgk/gsgg/202201/t20220105_5807792.htm

[38] "Analysis of the 2023 NdFeB Market: Sintered NdFeB Raw Material Output Exceeds 230,000 Tons" [《2023 年钕铁硼市场现状分析：烧结钕铁硼毛胚产量超 23 万吨》], Qianzhan Industry Research Institute [前瞻产业研究院], 2023, at https://bg.qianzhan.com/report/detail/300/231128-023a60e8.html.

[39] Ibid.

High-End Chips and AI

The development of humanoid robots as the ultimate form of AI requires far more than large language models or multimodal AI—it demands high-end chips capable of processing complex sensory inputs, decision-making in real time, and dynamically controlling motion. Unlike software-based AI, which operates in digital environments, humanoid robots must interact with the real world, requiring efficient computing, advanced algorithms, and massive data processing power to function autonomously. The ability to perceive, reason, and act in a human-like manner places extreme computational demands on AI chips, making cutting-edge semiconductor technology a fundamental pillar of robotic AI development.
China's recent advancements in AI, particularly with DeepSeek, demonstrate a leap forward in efficient algorithm design. DeepSeek's ability to optimize model efficiency, data processing, and computational costs makes it an optimal option in the field of robotic AI, where affordability and performance must be balanced. Unlike traditional industrial robots, humanoid robots require precise motor control, adaptive learning, and complex interaction capabilities, all of which depend on motion control units (MCUs) and AI-enhanced system-on-chips (SoCs) to integrate perception, cognition, and execution seamlessly.[40] As humanoid robotics evolve, these AI processors will need to support multimodal learning, predictive decision-making, and real-time environmental adaptation, pushing beyond the capabilities of conventional AI models.

China's efforts to develop AI chipsets, neural network accelerators, and brain-inspired computing reflect its ambition to lead in the AI-driven robotics revolution. As the physical embodiment of AI, humanoid robots will require continuous advancements in hardware efficiency, low-power computing, and high-speed data integration. However, export controls and the systemic lack of high-end chips present significant obstacles that China must overcome during this experimental phase, which demands extensive resources. The U.S. Department of Commerce has introduced comprehensive export controls aimed at weakening China's domestic semiconductor ecosystem, thereby hindering its ability to manufacture advanced chips locally. These restrictions exacerbate the challenges in developing the necessary computational infrastructure for advanced AI applications, including humanoid robotics. Consequently, China faces the critical task of achieving self-reliance in semiconductor production to ensure the sustainable advancement of its AI and robotics industries.

China's robotics AI ecosystem

China's AI and robotics ecosystem has seen significant growth, with major companies driving innovation in humanoid robotics and embodied intelligence. These firms are pioneering advancements in robotic hardware, AI integration, and industrial automation, positioning China as a leader in next-generation intelligent robotics.

[40] "In-Depth Report on Artificial Intelligence – Robotics Series: Technology Section" [《人工智能深度报告--机器人系列技术篇》], CSDN, 2024

Company	Key Focus	Notable Product	Key Innovation	Market Strategy
Unitree Robotics (宇树科技)	Quadruped and humanoid robots	Unitree G1 (2024) - Humanoid robot priced at ¥99,000 with advanced mobility	Pioneering in legged robots, expanding into humanoid robotics	Large-scale deployment in industrial and commercial applications
UBTech Robotics (优必选)	Humanoid robots for education, logistics, security, and commercial use	Walker S1 - Achieved 25% efficiency improvement, targeting cost reduction below $50,000 by 2025	First Chinese company to commercialize large-scale humanoid robots	Expanding humanoid robot accessibility through cost reduction
Fourier Intelligence (傅利叶智能)	Rehabilitation and humanoid robotics	GR-1 (2023) - Human-like mobility with proprietary FSA actuator for optimized motion	Developed in-house FSA actuator for improved power efficiency	Positioning as a leader in China's humanoid robotics sector
Agibot (Zhiyuan Robotics) (智元机器人)	AI and humanoid robotics	Far Expedition A1 - Features PowerFlow joint motor and SkillHand dexterous hand	Proprietary joint motor and dexterous hand with fingertip vision sensors	Accelerating commercialization in interactive services and manufacturing
Xiaomi Robotics (小米)	Consumer electronics and robotics	CyberDog (2021), CyberOne (2022), CyberDog 2 (2023) - Advancing AI-powered robots	Integrating AI and cost-effective manufacturing for mass adoption	Leveraging AIoT expertise to scale robotics for mass adoption

Source: Jamestown's database on PRC's Robotics Ecosystem

Huawei is actively building an ecosystem for embodied AI, integrating large models, edge computing, and robotic intelligence. In November 2024, Huawei (Shenzhen) Global Embodied Intelligence Industry Innovation Center officially commenced operations, aiming to accelerate breakthroughs in humanoid robotics. Huawei has partnered with Leju Robotics, Dazhou Robotics, Tuosida, Zhongjian Technology, and Zhaowei Electromechanical, among others, to drive collaborative innovation in AI-powered robotics.[41] Huawei's expertise in AI chipsets, cloud computing, and machine learning is expected to play a crucial role in advancing humanoid robotic intelligence and real-world applications.

III. China's Military Robotics

[41] "Huawei (Shenzhen) Global Embodied Intelligence Industry Innovation Center Set to Launch in Collaboration with Qianhai and Bao'an" [《携手前海、宝安，华为（深圳）全球具身智能产业创新中心即将启动运营》], Qianhai Government, 2024, at https://qh.sz.gov.cn/sygnan/qhzx/dtzx/content/post_11734159.html.

Domestic Drone Development Outlook

Year	Milestone Achievement
2022	Drone technology reaches world-class standards.
2023-2024	The Army and Air Force begin accelerating drone deployment.
2025	Establishment of a globally competitive drone system production network.
2035	Strong independent innovation capabilities to lead global drone industry, meeting world-class military standards.

Source: "White Paper on Unmanned Aerial System Development (2018)" [42]

The Strategic Development of Military Drones in China

The development of military drones in China has been a key strategic priority, aligning with the broader vision of modernizing the country's defense capabilities. President Xi Jinping, during his visit to the Air Force Aviation University on July 23, 2020, emphasized the growing role of unmanned combat systems in transforming modern warfare. He underscored the necessity of strengthening research in unmanned combat, enhancing UAV-related education, and accelerating the training of drone operation and command personnel.[43] These directives have significantly influenced China's UAV (Unmanned Aerial Vehicle) strategy, driving research and development in autonomous aerial combat technologies.

China has laid out an ambitious roadmap for UAV development. According to the Aviation Industry Corporation of China's (AVIC) White Paper on UAV Systems Development published in 2018, the country aims to establish a comprehensive, high-end UAV system by 2025. This system will feature breakthroughs in key technologies, a well-structured industrial ecosystem, and globally competitive production capabilities. Looking ahead to 2035, China's goal is to achieve global leadership in UAV technology, ensuring self-sufficiency in critical defense applications, and positioning itself at the forefront of industrial drone markets. The Air Force has confirmed that China's UAV technology has already reached world-class standards and that further collaboration with the defense industry is underway to develop next-generation UAV platforms.[44]

Military drones have become an essential element in "new domain and new quality" combat forces, leveraging advanced information technology and artificial intelligence for strategic aerial

[42] "White Paper on Unmanned Aerial Systems Development (2018)" [《无人机系统发展白皮书（2018）》], Aviation Industry Corporation of China (中国航空工业集团有限公司), 2018.
[43] "Xi Jinping Emphasizes Deepening Reform and Innovation to Continuously Improve Education Quality During Visit to Air Force Aviation University Before August 1st" [《习近平八一前夕视察空军航空大学时强调 深化改革创新 不断提高办学育人水平》], The State Council of the People's Republic of China, 2020, at https://www.gov.cn/xinwen/2020-07/23/content_5529519.htm.
[44] "White Paper on Unmanned Aerial Systems Development (2018)" [《无人机系统发展白皮书（2018）》], Aviation Industry Corporation of China (中国航空工业集团有限公司), 2018.

operations.[45] As China focuses on long-range precision strikes, intelligent warfare, stealth technology, and unmanned combat, military drone development is receiving strong policy support. The integration of civil-military research collaborations and industrial innovation has further accelerated advancements in China's drone industry, fostering a robust ecosystem for both military and commercial applications.

Aircraft Platform and Flight Systems

At the core of any drone is its airframe and aerodynamic design, which dictate structural integrity, maneuverability, and mission adaptability. A drone's layout depends on its operational role, with fixed-wing drones excelling in endurance and speed, while rotorcraft designs provide superior agility and vertical takeoff capabilities.[46] The flight system integrates propulsion, navigation, and onboard control units, forming the backbone of the drone's autonomous flight capabilities.[47]

Power Systems: The Heart of Drone Performance

A drone's propulsion system significantly impacts its payload capacity, endurance, altitude, and speed. Propulsion solutions vary across drone classes, ranging from electric motors in micro-drones to advanced turbine engines in high-altitude, long-endurance UAVs.[48] Gas turbine engines such as turbojets and turbofans enable high-speed reconnaissance and combat operations, whereas turbo-prop and piston engines offer extended endurance for surveillance missions. With the increasing need for high-altitude, high-speed drones, the demand for turbojet and ramjet engines is expected to rise, supporting next-generation unmanned combat aircraft.[49]

Mission Payloads: Intelligence, Surveillance, and Combat Capabilities

The effectiveness of a drone is largely determined by its mission payloads, which include optical sensors, synthetic aperture radar (SAR), and weaponry. Optoelectronic payloads serve as the "eyes" and "brain" of drones, enabling real-time reconnaissance, target identification, and battlefield situational awareness. Multi-spectral imaging, including visible light, infrared, and laser detection, allows drones to operate effectively in diverse combat environments. Leading Chinese companies such as AVIC Optoelectronics, StarNet YuDa, and Dali

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[45] "A Batch of New Strategic and Advanced Combat Forces Unveiled: 'Major Power Equipment' Showcases 'Hardcore' Strength" [《一批新域新质作战力量最新成果纷纷亮相 "大国重器"展现"硬核"力量》], CCTV (央视网), November 14, 2024, at https://news.cctv.com/2024/11/14/ARTIOBCv1nIVPraEJTswNU7C241114.shtml.

[46] "Basic Knowledge of Drones: Fundamental Components of a Multi-Rotor UAV System" [《无人机基础知识：多旋翼无人机系统基本组成》], CSDN, at https://blog.csdn.net/qq_32761549/article/details/127102797.

[47] "Analysis of Low-Altitude Intelligent Networks and UAV Industry Applications" [《浅析低空智联网与无人机产业应用》], Fan Bangkui (樊邦奎), Li Yun (李云), Zhang Ruiyu (张瑞雨), Progress in Geography [《地理科学进展》], Vol. 40, Issue 9, 2021.

[48] Ibid.

[49] "Building Intelligent Unmanned Flight with 'China Technology'" [《构建智能无人飞行的"中国技术"》], United Aircraft Corporation [联合飞机集团], Total Issue No. 2, July 2022.

Technology specialize in developing high-performance optical pods for reconnaissance and targeting.[50]

Synthetic Aperture Radar: Overcoming Limitations of Optical Reconnaissance

SAR technology is crucial for day-night, all-weather battlefield imaging, overcoming the vulnerabilities of optical sensors in adverse conditions. While traditional reconnaissance UAVs rely on infrared and visual cameras, they are limited by poor visibility and atmospheric conditions. SAR-equipped drones offer unparalleled battlefield intelligence, with the ability to penetrate cloud cover and camouflage, making them indispensable for modern warfare. China has made significant strides in miniaturizing SAR payloads for UAV integration, allowing for high-resolution real-time mapping and strategic target acquisition. As UAVs continue to evolve, SAR technology will play a key role in expanding their operational effectiveness across multiple domains.[51]

Notable Trends

China's military UAV development follows three major technological trends: stealth, intelligence, and anti-jamming capabilities. The emphasis on stealth technology has led to the adoption of radar-absorbing coatings, infrared suppression materials, and structural modifications that reduce the Radar Cross Section (RCS) and infrared signatures of drones. These advancements enhance survivability in contested environments by improving battlefield concealment and reducing vulnerability to enemy detection and interception. Furthermore, artificial intelligence is playing a crucial role in advancing UAV autonomy.[52] Modern Chinese drones are being developed to execute three primary modes of intelligent combat: autonomous missions, multi-UAV swarm coordination, and human-machine collaborative operations. The increasing use of AI-driven swarm technology allows drones to share real-time data, conduct coordinated attacks, and enhance reconnaissance capabilities. However, achieving full autonomy in combat UAVs remains a challenge that requires sophisticated machine learning and real-time decision-making algorithms. Moreover, military drones must possess robust anti-jamming features to ensure resilience against electromagnetic interference, cyber threats, and electronic countermeasures deployed by adversaries.[53] These capabilities are essential for maintaining operational effectiveness in modern electronic warfare scenarios.

China's Dominance in Combat Drones and Global Market Expansion

China has rapidly emerged as a dominant player in the global UAV export market, driven by the high performance and cost-effectiveness of its drone systems. Between 2010 and 2020, China accounted for 17% of global military UAV exports, ranking third after Israel (31%) and the United States (28%). By 2024, China's share in the global military drone market is projected to

[50] Ibid.
[51] Ibid.
[52] "Research on the Development, Application, and Main Combat Patterns of Key Military UAV Technologies" [《军用无人机关键技术发展应用及主要作战样式研究》], Miao Zhuang (苗壮) et al., Flight Missile [《飞航导弹》], September 2020.
[53] Ibid.

rise to 25%, with an estimated market valuation of $4.025 billion.[54] Demand for Chinese UAVs is particularly strong in developing countries across the Middle East, Southeast Asia, and Africa, where cost-effective, high-performance drones provide a viable alternative to Western defense systems.

Among China's most successful UAV platforms, the Wing Loong and CH-series drones stand out as flagship products with widespread global deployment. The Wing Loong series, developed by Chengdu Aircraft Industry Group (CAIG), includes a range of long-endurance reconnaissance and strike UAVs. The Wing Loong-1 was China's first export-oriented medium-altitude long-endurance (MALE) UAV and has been widely deployed in countries such as Pakistan, the United Arab Emirates, Saudi Arabia, and Egypt. The Wing Loong-1D introduced an all-composite design, improving durability and operational performance, while the Wing Loong-2 became China's first turboprop-powered combat UAV, significantly expanding mission range and payload capacity. The CH-series drones, developed by Aerospace CH UAV Corporation, have been China's most commercially successful UAV exports. The CH-4 UAV, known for its affordability and combat efficiency, has set a benchmark for China's UAV exports, with deployments in over ten Belt and Road Initiative (BRI) countries.[55][56]

China's UAV industry is supported by an extensive and vertically integrated supply chain. The upstream segment includes raw materials such as metal and composites, as well as advanced electronic components including avionics and AI chipsets. Midstream players specialize in manufacturing flight platforms and mission payloads, integrating optical sensors, synthetic aperture radar (SAR) systems, and advanced propulsion units. Downstream manufacturers focus on assembling complete UAV systems for military and civilian applications. The industry is dominated by state-owned enterprises such as the Aviation Industry Corporation of China (AVIC). The rapid evolution of China's UAV industry underscores its commitment to achieving technological self-reliance and enhancing global competitiveness. With continued investment in AI-driven flight autonomy, advanced reconnaissance capabilities, and integrated electronic warfare systems, China's drone sector is set to play a pivotal role in shaping the future of unmanned combat and intelligence operations. [57]

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[54] "2011-2021 China's Military UAV Export Models and Quantity Proportions" [《2011-2021 年中国军用无人机出口型号及数量占比》], Everbright Securities Research Institute [光大证券研究所], at https://www.hangyan.co/charts/3028387951395473295.

[55] "Wing Loong-X and Over 20 Domestic Military UAVs Debut at Airshow, UAV Coordination System Becoming More Advanced" [《翼龙-X 等二十余型国产军用无人机亮相航展 无人机协同体系日益完备》], Xinhua News Agency [新华网], November 14, 2024, at https://archive.ph/BDaTg.

[56] "China's Increasing Global Drone Footprint" [China's Increasing Global Drone Footprint], Dr. Abhishek Kumar Darbey, Institute for Defence Studies and Analyses (IDSA), 2024, at https://www.idsa.in/publisher/comments/chinas-increasing-global-drone-footprint/.

[57] "Comparison of Chinese and American Drones and Their Implications" [《中美无人机对比及其启示》], He Jiangyan (何江彦), Zuo Xianzhang (左宪章), Zheng Yijie (郑翌洁), China Modern Educational Equipment [《中国现代教育装备》], 2020.

Military Robotics: Quadrupedal Robotic Dogs

The emergence of quadrupedal robotic dogs marks a significant advancement in military robotics, offering unique operational advantages in reconnaissance, battlefield engagement, and logistical support. These four-legged robotic platforms are designed to maneuver diverse terrains with high mobility, performing actions such as advancing, lying down, jumping, and retreating. Equipped with AI-powered navigation systems, they can autonomously map their surroundings, avoid obstacles, and engage in mission-specific tasks, making them a crucial asset in modern warfare.[58]

China has made significant strides in the development of quadrupedal robotic dogs, rapidly advancing their capabilities for military applications. The integration of artificial intelligence enables these robotic platforms to autonomously identify targets, determine optimal engagement timing, and adjust movement patterns based on real-time battlefield conditions. The versatility of these robotic dogs allows them to conduct reconnaissance missions by transmitting real-time intelligence to command centers, execute direct combat roles by carrying rifles or other weaponry, and assist in command-and-control operations by managing logistical support and tactical coordination.

China's rapid progress in this field was demonstrated at the 2022 Zhuhai Airshow, where China North Industries Corporation (Norinco) 58 Institute unveiled its independently developed quadrupedal robotic system. This robotic dog exhibited high maneuverability, heavy payload capacity, and multi-terrain adaptability, making it suitable for reconnaissance, fire suppression, cooperative assaults, hazardous material handling, and supply transportation.[59] The latest iteration of this robotic platform was showcased again in 2024 during the Sino-Cambodian "Golden Dragon" joint military exercises, highlighting its enhanced reconnaissance and combat functionalities. The reconnaissance variant of this robotic dog is lightweight and agile, equipped with LiDAR sensors and cameras for intelligence gathering, while the combat variant, weighing approximately 100 pounds, can be armed with automatic rifles and other weaponry, operated remotely by military personnel.[60]

At the 2024 Zhuhai Airshow, Norinco 58 Institute further unveiled an advanced quadrupedal robotic team under the "Machine Wolf" program, featuring modularized robotic units specializing in distinct battlefield roles. The reconnaissance Machine Wolf gathers intelligence through optical and infrared sensors, the logistics Machine Wolftransports ammunition and supplies, and the precision strike Machine Wolf utilizes real-time data to engage targets with

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[58] "CCTV Exposes PLA Exercise: Tanks and Robot Dogs Deployed, A Wake-Up Call for U.S. Military on the Island"[《央视曝光解放军演习：坦克和机器狗集体出动，美军给岛内提了个醒》], Baijiahao, 2025, at https://baijiahao.baidu.com/s?id=1821912177769225156.

[59] "AI Empowering the Defense Industry as a New Trend, Ground Robots Expected to Enter Combat First" [《AI 赋能军工成为新趋势，地面机器人有望率先走向实战》], Baijiahao, 2025, at https://baijiahao.baidu.com/s?id=1819222659499380264.

[60] "One Step Ahead of the U.S.!' U.S. Media Claims PLA's Robot Dogs Have Become Urban Warfare Weapons"[《"领先美国一步！"美媒称解放军机器狗成巷战利器》], Xinhua News Agency [新华网], 2024, at http://www.xinhuanet.com/mil/2024-05/27/c_1212366008.htm.

mounted firearms.[61] This modular organization enables high levels of autonomous coordination and intelligent decision-making, demonstrating China's increasing sophistication in AI-driven robotic warfare.

China North Industries Corporation (Norinco) has played a leading role in these developments. Originally established as the 58th Research Institute in 1977, the organization underwent restructuring and is now a key subsidiary of China North Industries Group Corporation Limited. The company has set forth a strategic mission of enhancing weapon system intelligence and battlefield automation, positioning itself as a major force in the mechanization, informatization, and intelligentization of Chinese defense systems.[62]

Another major contributor to China's military robotics sector is Chongqing Jianshe Industry (Group) Co., Ltd., a key subsidiary of China South Industries Group Corporation, one of China's largest defense manufacturers. As part of its expansion into military robotics, Chongqing Jianshe showcased a fully weaponized heavy quadrupedal robotic dog at the 2024 Zhuhai Airshow, emphasizing its strategic focus on integrating robotics with advanced firepower systems.[63]

China's military robotics sector is also witnessing increasing participation from private enterprises, driving innovation and competition within the defense industry. Companies like Beijing Jingpin Special Equipment (晶品特装) and Beijing Emerging Equipment Technology (新兴装备) have become key suppliers of specialized reconnaissance and combat robotics. The former has successfully developed a range of military robots and optical sensor systems that have been integrated into frontline military units and special operations forces.64 The latter is a high-tech enterprise focused on unmanned aerial systems, electromagnetic weaponry, and advanced aviation technology, providing AI-driven weapon integration solutions for China's defense sector.[65] China's advancements in quadrupedal robotic dogs and battlefield AI systems reflect its broader goal of achieving technological dominance in intelligent

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[61] "From 'Robot Dogs' to 'Robot Wolves': These Adorable Machines Can Now 'Fight in Teams'!" [《"机器狗"到"机器狼"，这些呆萌的家伙能"打团战"了！》], Hunan Daily [湖南日报], 2024, at https://baijiahao.baidu.com/s?id=1815752284527659269.

[62] "Research on the Development, Application, and Main Combat Patterns of Key Military UAV Technologies" [《军用无人机关键技术发展应用及主要作战样式研究》], Miao Zhuang (苗壮) et al., Flight Missile [《飞航导弹》], September 2020.

[63] "Chongqing Construction Industry Group Showcases Robot Dogs to Foreign Militaries at the 2024 Zhuhai Airshow" [《2024年珠海航展上重庆建设工业集团机器狗向外军进行动态展示》], Bilibili, 2024, at https://www.bilibili.com/video/BV1sdzmYEEUX/

[64] "Beijing Jingpin Special Equipment Technology Co., Ltd. Official Website" [《北京晶品特装科技股份有限公司官方网站》], Beijing Jingpin Special Equipment Technology Co., Ltd. (晶品特装), at https://jp-tz.com/gsjj.

[65] "Beijing Emerging Eastern Aviation Equipment Co., Ltd. Company Profile" [《北京新兴东方航空装备股份有限公司公司简介》], Beijing Emerging Eastern Aviation Equipment Co., Ltd. (新兴装备), at https://www.qcc.com/product/1927ba7a-6a6b-4380-b823-2d6823231d10.html.

warfare. With an increasing focus on machine autonomy, networked warfare, and AI-driven battlefield analytics, China is positioning itself as a leader in the next-generation military robotics revolution.

Undersea Robotics: Autonomous Unmanned Underwater Vehicles (UUVs) and Military Applications

The development of undersea robotics is a critical aspect of China's "Made in China 2025" (MIC 2025) strategy, which seeks to advance high-tech industries, including autonomous manufacturing, deep-sea exploration, and naval defense. Unmanned Underwater Vehicles (UUVs) and Autonomous Underwater Vehicles (AUVs) serve dual-use purposes, supporting marine research, deep-sea resource exploration, undersea infrastructure maintenance, and military operations. These systems provide China with strategic advantages in maritime surveillance, anti-submarine warfare, and mine countermeasures, aligning with national objectives to establish a stronger maritime defense system.[66]

China's UUV development has expanded rapidly, with a growing focus on deep-diving endurance, AI-driven autonomy, and enhanced sensor capabilities. The Haiyan underwater glider (海燕), developed by Shanghai Jiao Tong University, can operate autonomously for over 200 days, reaching depths of 1,000 to 1,500 meters, making it a key asset for long-duration oceanographic monitoring. The HSU-001 UUV, unveiled during the 2019 National Day Parade, showcases China's advancements in military-grade undersea drones, potentially designed for reconnaissance, anti-submarine warfare, and underwater combat support.[67]

China's UUV advancements have been driven by leading state-owned defense conglomerates, particularly China Shipbuilding Industry Corporation (CSSC) (中船重工). CSSC, as the largest shipbuilding enterprise in China, is spearheading the development of large-displacement UUVs (LDUUVs) and undersea surveillance systems. Groups in the industry work on improving UUV stealth, endurance, and multi-mission adaptability, critical to China's long-term naval strategy.[6869]

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[66] "The 'Dark Horse' Entering the Underwater Battlefield: Unmanned Underwater Vehicles" [《闯入水下战场的"黑马"：无人潜航器》], China Military Online – PLA Daily [中国军网-解放军报], April 2024, at http://www.81.cn/yw_208727/16303868.html.

[67] "Current Research Status and Prospects of Unmanned Underwater Vehicles" [《水下无人航行器的研究现状与展望》], Armed Police Research Institute [武警研究院], December 2023.

[68] "Global Research Frontiers Identification and National Development Layout of Underwater Vehicles" [《水下潜器全球研发前沿识别与国家研发布局》], Wang Yunfei (王云飞), Wang Zhiling (王志玲), Song Wei (宋伟), Chu Zhiyong (初志勇), Xue Zhao (薛钊), 2022.

[69] "The 'Dark Horse' Entering the Underwater Battlefield: Unmanned Underwater Vehicles" [《闯入水下战场的"黑马"：无人潜航器》], China Military Online – PLA Daily [中国军网-解放军报], April 2024, at http://www.81.cn/yw_208727/16303868.html.

While China has successfully demonstrated UUV prototypes, the mass deployment and integration of these systems into naval fleets remain an ongoing challenge. Underwater docking, extended mission autonomy, and real-time data transmission are areas where further technological advancements are required. Given the increasing geopolitical tensions in the South China Sea and Pacific region, China is accelerating UUV deployment for naval superiority. Efforts to establish a networked underwater Great Wall, integrating UUV surveillance systems, deep-sea listening arrays, and AI-driven reconnaissance platforms, highlight the strategic importance of underwater autonomous warfare in China's defense strategy.

IV. Challenges Facing China's Robotics Industry

China's robotics industry has seen remarkable progress, driven by national policies such as Made in China 2025, rapid industrial automation, and advancements in AI-driven robotics. However, despite these achievements, the sector faces several challenges that could slow its progress and limit its competitiveness in key global markets.

High Costs and Material Limitations in Lightweight Robotics

One of the biggest technological and economic challenges in China's robotics industry is the high cost of lightweight materials, which is essential for improving energy efficiency, reducing operational costs, and expanding robotic applications. Lightweight robotics are particularly critical for autonomous service robots, medical robotics, and space applications, where reducing weight directly enhances mobility, energy consumption, and safety.

One of the most promising materials considered by China for lightweight robotics is PEEK (Polyether ether ketone) (聚醚醚酮), a high-performance engineering plastic that combines low density, high strength, corrosion resistance, and excellent mechanical properties. PEEK offers the potential for replacing steel in industrial applications, significantly reducing robot weight while maintaining durability.[70]

However, China remains dependent on foreign imports for high-quality PEEK production, with leading global manufacturers such as Victrex (United Kingdom), Solvay (Belgium), and Evonik (Germany) dominating the market. Chinese companies, PanJin Zhongrun (盘锦中润) and Jilin Zhongyan (中研高能), are catching up behind.[71] If China cannot be self-sufficient in this area, its robotics industry may struggle to meet the demands of high-mobility applications, including surgical robots, humanoid robots, and space-exploration robotics, where weight is a critical factor in efficiency and performance.

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[70] "Humanoid Robot Industry Sees Rapid Growth, PEEK Material Demand Expected to Surge" [《人形机器人产业迎来密集催化，PEEK 材料需求增速有望更趋陡峭》], Baijiahao, 2025, at https://baijiahao.baidu.com/s?id=1822089006710581172.

[71] "Polyetheretherketone (PEEK) Market Size Expected to Hit USD 1.7 Billion by 2034 with a 7.4% CAGR Increase" [Polyetheretherketone (PEEK) Market Report], Transparency Market Research, 2024, at https://www.globenewswire.com/news-release/2024/09/27/2954741/0/en/Polyetheretherketone-PEEK-Market-Size-Expected-to-Hit-USD-1-7-Billion-by-2034-with-a-7-4-CAGR-Increase-Exclusive-Report-by-Transparency-Market-Research-Inc.html.

Dependence on Foreign High-End Components and Industrial AI

Despite its rapid advancements in AI and automation, China remains reliant on foreign-made high-end components for industrial and humanoid robots, particularly in precision actuators, high-torque servo motors, AI processors, and advanced sensors. The domestic supply chain for robotic intelligence and industrial AI chips is still in its early stages, and companies continue to import key components from Japan, Europe, and the United States.

The lack of a fully independent AI and semiconductor ecosystem hinders China's ability to scale robotic intelligence and autonomy. AI-driven robotics require powerful computing infrastructure to process vast amounts of real-time data, enabling functions such as visual recognition, movement prediction, and autonomous decision-making. While China has made strides with AI companies like DeepSeek and Huawei Ascend AI, a handful of "unicorn enterprises" are still unmatched to the U.S. broad ecosystem. A well-executed U.S. export controls on high-end GPUs, AI chips and potential legacy chip can significantly limit China's ability to train advanced robotics models in a long run.

The Industrial Robotics Gap

While China is the world's largest market for industrial robots, its domestic robotics industry is still underdeveloped in key areas, particularly in high-end automation and humanoid robotics. A significant portion of China's industrial robots are low-tech mechanical arms focused on simple tasks such as material handling (55%) and welding (25%), with relatively low precision and intelligence.[72] China's industrial robots are thus not yet capable of fully addressing its aging workforce crisis, which is expected to severely impact economic productivity in the coming decades. The country's rapidly shrinking labor force necessitates a large-scale shift to automation, but current industrial robotics adoption remains highly concentrated in automotive manufacturing and electronics assembly.

Another major challenge is the development of mobile industrial robots, such as AGVs (Automated Guided Vehicles) and ACRs (Autonomous Case-handling Robots), which have grown rapidly but still lack advanced AI-driven decision-making capabilities. It remains to be seen whether China can make a leap in industrial AI and eventually deploy it at scale to offset labor shortages.

PLA Decision-Making Challenges in Autonomous Military Robotics

One of the most profound challenges facing China's military robotics development is the structural conflict between centralized PLA decision-making and the real-time autonomy required for advanced AI-driven combat platforms. The PLA operates under a highly centralized command structure, emphasizing strict hierarchical control. While this system ensures political oversight and coordination, it is fundamentally at odds with the core advantage of AI-driven

[72] "2022 China Industrial Robot Market Research Report" [《2022 中国工业机器人市场研究报告》], EO Intelligence [亿欧智库], 2022

autonomous warfare—the ability to process battlefield data and make split-second tactical decisions faster than human operators.

Autonomous military platforms, such as AI-powered drones, robotic infantry units, and swarm-based warfare systems, require a level of decision-making independence that the PLA may be unwilling to grant. The PLA's reluctance to fully delegate combat decisions to AI systems could limit the effectiveness of its autonomous weapons programs.

However, this concern may be mitigated over time through continuous military drills, real-world data collection, and AI model refinement. By conducting large-scale military exercises, the PLA can improve its ability to integrate AI-assisted decision-making into its command structure, allowing for greater trust in autonomous systems while maintaining strategic oversight.

V. China's Autonomous Dominance: Future Economic and National Security Challenges for the United States and Its Allies

China's rapid advancements in autonomous technologies pose profound economic and national security challenges to the United States and its allies, reshaping the balance of power in AI-driven warfare, autonomous combat systems, and strategic defense technologies. As China aggressively invests in robotic AI, intelligent combat systems, and cost-effective military automation, it challenges U.S. technological superiority while increasing its global defense influence.

The Rise of Humanoid Robotics and "Physical AI" Leadership

The future of AI is physical—a concept endorsed by industry leaders, who argue that humanoid robotics and embodied AI represent the ultimate evolution of artificial intelligence, far beyond the current capabilities of LLMs (large language models) and multimodal AI. While chatbots and digital assistants have revolutionized information processing, the next frontier is AI-powered physical automation, where humanoid robots replace human labor across industries, defense, and logistics.

China has positioned itself at the forefront of humanoid robotics, surpassing global competitors in production, deployment, and market influence. Companies like UBTech, Fourier Intelligence, Xiaomi, and Unitree Robotics have not only pioneered humanoid robot development but also established dominant market shares in both commercial and industrial robotics. As the demand for autonomous labor surges, downstream customers—including logistics, manufacturing, medical, and security sectors—are increasingly dependent on Chinese robotics solutions, limiting alternative suppliers for Western economies.

From a military standpoint, humanoid robots will play an essential role in next-generation warfare, acting as autonomous battlefield units, logistics operators, and AI-driven combat assistants. These machines are highly mobile, adaptable to unpredictable environments, and capable of executing complex military tasks, making them a crucial force multiplier in future conflicts. If China maintains its leadership in humanoid robotics, the U.S. risks falling behind in

both military automation and AI-driven economic transformation, further weakening its industrial and defense capabilities.

AI-Enabled Warfare: Battlefield Autonomy and Decision Superiority

China's integration of AI-driven decision-making systems into operations is reshaping its military. The development of battlefield intelligence networks, autonomous mission planning, and predictive combat analytics enables China's military to process real-time data, anticipate enemy movements, and automate strategic decisions at speeds unmatched by traditional command structures.

China is actively developing AI-powered war-gaming simulations, where machine learning algorithms train on real-world combat data, continuously improving tactical coordination between human soldiers, UAVs, and robotic combat units. This autonomous battle management system gives China the ability to coordinate large-scale military operations with minimal human intervention, drastically improving combat efficiency.[73]

Unlike the U.S., which predominantly manufactures high-end military UAVs, China produces a full spectrum of drones, ranging from low-cost, expendable UAVs to microdrones and sophisticated, stealth-capable combat drones. Also, China's integrated reconnaissance-strike UAVs, such as the Wing Loong II and CH series, directly compete with U.S. MQ-9 Reapers, but at a fraction of the cost.[74] This diversified portfolio provides greater operational flexibility, allowing China to experiment with new combat doctrines.

Unmanned Combat Drones and Swarm Warfare

China's growing dominance in unmanned aerial vehicles (UAVs) poses both economic and military threats to the United States. The development of low-cost, high-performance UAVs like the Wing Loong and CH series has allowed China to flood the global defense market, providing cost-effective alternatives to U.S. and Israeli drone systems. Countries that cannot access U.S. military technology due to export restrictions increasingly turn to China, strengthening its geopolitical influence and eroding U.S. military alliances.[75] [76]

Beyond traditional drones, China's rapid advancements in UAV swarming technology create a new asymmetric threat against the U.S. and its allies. Swarm tactics enable hundreds of AI-

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[73] "What's 'New' in New-Domain and New-Quality Combat Forces?" [《新域新质作战力量"新"在哪里》], Ministry of National Defense (MND), 2022, at https://archive.ph/nuS4D#selection-215.0-215.14.

[74] "Analysis of U.S.-China UAV Development" [《中美無人機發展評析》], Lin Zongda (林宗達), International Military Affairs Magazine Publishing House [國際軍務雜誌社], 2024.

[75] "Research on Manned/Unmanned Aerial Vehicle Cooperative Combat Modes and Key Technologies" [《有人/无人机协同作战模式及关键技术研究》], Sun Shengzhi (孙盛智) et al., Aviation Weaponry [《航空兵器》], October 2021

[76] "Research on the Composition and Operational Concepts of Drone Swarm Warfare" [《无人机蜂群作战构成及作战概念研究》], Yang Lina (杨丽娜) et al., Modern Defense Technology [《现代防御技术》], August 2020

coordinated drones to perform synchronized reconnaissance, electronic warfare, and precision strikes, overwhelming enemy defenses, including U.S. naval assets in the Indo-Pacific. These swarms could be weaponized against aircraft carriers, military bases, and strategic installations, reducing the effectiveness of traditional missile defense systems.

Economic and Strategic implications for the U.S. and Its Allies

China's dominance in autonomous technology extends beyond military threats, posing economic and strategic risks. Its leadership in AI, robotics, and drones is reshaping industries, reducing U.S. influence, and creating supply chain dependencies on Chinese infrastructure. As China exports these technologies globally, U.S. and allied economies risk long-term reliance on Chinese AI and automation. Cybersecurity concerns further escalate as China's AI-driven surveillance and cyber warfare capabilities threaten global infrastructure. The potential for AI-enabled espionage, cyberattacks, and electronic warfare raises national security risks beyond traditional battlefield applications. If unchecked, China's technological rise could outpace the U.S. in both military and economic domains. To counter this, the U.S. must accelerate investments in AI warfare, autonomous robotics, and cybersecurity to maintain its strategic and technological edge.

VI. Recommendations for U.S. Policymakers

1. **To counter China's systematic advancements in robotics, the U.S. government should establish a National Robotics Strategy Committee.** Modeled after previous AI and Biosecurity task forces, to coordinate interagency efforts and align national policies with industrial expertise. Given China's dominance in robotic and autonomous technologies, it is critical that the U.S. government fully understands the complex ecosystem of key components, supply dependencies, and industrial capabilities in both industrial and military robotics. The new committee can -

- Map out the robotic supply chain, identifying domestic vulnerabilities in steel alloys, lightweight materials (e.g., PEEK, carbon fiber, magnesium), AI-driven control chips, actuators, precision motors, sensors (IMU, torque, vision, force), battery systems, and high-end semiconductors.
- Analyze global dependencies and monitor key Chinese robotics firms, including actuator manufacturers, gear reducers (e.g., harmonic drives), industrial motors, robotic vision processors, and AI chips, to mitigate reliance on adversarial supply chains.
- Engage with industry leaders and academia to guide U.S. industrial policy, working with leading robotics firms, industrial automation leaders, semiconductor companies, and material science firms to advance domestic robotics capabilities.
- Recommend investment and export control measures to onshore critical manufacturing, restrict Chinese access to sensitive AI-driven robotic technologies, and support trusted suppliers in allied nations (e.g., Japan, South Korea, Germany).

2. **To effectively respond to China's technological and economic advancements, the U.S. government should establish a dedicated Open-Source Intelligence (OSINT) Agency**. It should focus on training experts who understand the Chinese languages and

social context to track, analyze, and predict global technological developments, particularly in robotics, AI, and autonomous military platforms. Given that much of China's progress in these fields is documented in state media, research papers, industrial reports, patents, supply chain data, and investment disclosures, a dedicated OSINT agency would leverage publicly available data to provide timely, strategic insights for policymakers and industry leaders.

- The agency should systematically track China's industrial policies (e.g., MIC 2025, Five-Year Plans), defense-related AI and robotics advancements, corporate strategies, and academic research to assess their long-term impact on U.S. competitiveness and national security.
- The agency should map out the origins of key technologies—such as high-end semiconductors, AI processors, robotic actuators, industrial sensors, autonomous military vehicles, and advanced materials—to identify U.S. vulnerabilities and potential leverage points in global trade.
- The agency would inform export control decisions, investment screening policies (CFIUS), and sanctions on adversarial firms. It could also help coordinate allies' responses to China's state-backed industrial dominance.
- The agency should integrate AI-driven data mining, NLP (natural language processing), and predictive analytics to efficiently process and extract insights from millions of patents, corporate reports, academic papers, trade data, and financial disclosures.
- The agency should help U.S. tech firms, venture capital and academia translate unclassified intelligence insights into actionable policies, ensuring that America's tech ecosystem remains competitive against China's industrial model.

3. **The U.S. must accelerate its adoption of AI-powered warfare technologies to prevent strategic disadvantages.** China is developing PLA-integrated AI warfare systems, including swarm UAVs, autonomous undersea drones (UUVs), and AI-driven battlefield analytics. The U.S. must accelerate its adoption of AI-powered warfare technologies to prevent strategic disadvantages and prioritize AI-integrated warfare research on autonomous decision-making in combat scenarios. The US should continue to enhance AI-augmented military drills to test human-AI coordination in real-world combat scenarios, refining AI decision-making algorithms.

4. **The U.S. should expand export controls to restrict China's access to high-performance AI accelerators, robotic control systems, and dual-use AI software.** China's autonomous military vehicles, humanoid robots, and AI-driven decision systems rely heavily on foreign semiconductor imports and AI chips. The U.S. should expand export controls to restrict China's access to high-performance AI accelerators, robotic control systems, and dual-use AI software. The U.S. should preemptively expand the U.S. Entity List to cover Chinese robotics and AI firms developing autonomous weapons, and work with Japan, South Korea, and the EU to tighten AI chip and robotics export restrictions, preventing China from bypassing U.S. sanctions.

5. **The U.S. must offer strategic alternatives to prevent countries from becoming dependent on Chinese autonomous systems.** China is aggressively exporting UAVs, robotic combat platforms, and AI-driven surveillance technologies to developing nations, expanding its military influence in Africa, the Middle East, and Southeast Asia. The US should expand U.S. defense technology exports to offer allies competitive alternatives to Chinese UAVs and autonomous weapons, and increase foreign military aid for AI-powered defense systems, ensuring allies can counter Chinese-made drone swarms and robotic combat units.

Appendix. China's Provincial Robotics Development Policies in 2024

Policy Name	Issuing Authority	Goals	Key Tasks
Jiangsu Province Robotics Industry Innovation Development Action Plan	Jiangsu Provincial Department of Industry & Information Technology	Achieve globally advanced industry standards	Enhance innovation capacity, accelerate core technology breakthroughs, and improve industrial foundations
Shandong Province Humanoid Robotics Industry Innovation Development Plan (2024-2027)	Shandong Provincial Department of Industry & Information Technology	Significant technological advancements, fostering 10 key enterprises with over 1 billion RMB in revenue	Accelerate technological innovation, strengthen product supply, and promote industrial ecosystem development
Shanghai Industrial & Service Industry Upgrade Action Plan (2024-2027)	Shanghai Municipal Government Office	Establish a National Humanoid Robotics Manufacturing Innovation Center and develop robotics production solutions	Create humanoid robotics-enabled manufacturing application scenarios
Zhejiang Province Humanoid Robotics Industry Innovation Development Plan (2024-2027)	Zhejiang Provincial Department of Economy & Information Technology	Cultivate 5+ high-level provincial innovation centers and 30 enterprise R&D institutions	Enhance supply chain integration, foster industry clusters, and diversify application scenarios
Chongqing Policies for Embodied AI & Robotics Industry Innovation	Chongqing Economic & Information Technology Commission	Advance key technologies, including integrated compute-storage chips and high-performance actuators	R&D focuses on integrated compute-storage chips, new sensors, and robotics operating systems

Anhui Province Humanoid Robotics Industry Development Plan (2024-2027)	Anhui Provincial Department of Industry & Information Technology	Develop the '23456' humanoid robotics innovation system and industrial ecosystem	Optimize full-machine manufacturing, strengthen advantages, address weaknesses, and build a sustainable ecosystem

PANEL I QUESTION AND ANSWER

VICE CHAIR SCHRIVER: Thank you very much, Mr. Cheung. Thank you, all three witnesses, again. Excellent statements. And we are going to begin the round of questioning, and for fellow Commissioners, we are going to in reverse alphabetical order, starting with the prerogative of the Co-Chairs. So I will lead off. That means I go first.

Dr. Endy, thank you again for your statement. You described the way we apply resources as basically inverted, we're focused more on applications, and I think your strong recommendation that we invest more in foundational biotechnology research. That still strikes me as somewhat of a broad category. Are there particular areas in the broad space of biotechnology foundational research that should have higher priority and move with a sense of urgency, and why might that be?

DR. ENDY: Thank you so much, Commissioner Schriver. It's a good question. Let me give you two examples. You know, you hear people talking about creating cloud laboratories. Imagine being able to script an experiment on a computer and it runs in a facility somewhere else. We are familiar with cloud computing, AWS, and so on and so forth. People are creating businesses, trying to make this real, and work on the market.

Imagine all of the foundational engineering truths that have to be figured out in order to have a network that actually works. If Cisco, long ago, wanted to make routers they needed to get wires to wire up correctly, and to get wires to wire up correctly we need to have things like units of resistance for electricity flowing through metal, things like the ohm. You know, if you are in physics you understand, oh, that is the unit of resistance for electrons going through wires.

So what are the units for genes turning on and off, for DNA being read out in a cell, for a fermentation process, making an energetic compound? The answer to all of these questions are crickets. We don't have metrology. The science of measurement worked out for bioengineering. And so what that means is all of our workflows are Edisonian -- tinker and test, tinker and test, do the best designing with your fancy iTools, but when you go and build the actual thing you have got to put it in a lab and hope and pray that it works, and you try and find the one thing that works, and maybe you have to do that a thousand times, physically prototyping.

So an example of high-leverage foundational research would be in biometrology, the weights and measures of the bioeconomy. Classically, in the United States, this has been done by Commerce through NIST. NIST has a Physical Measurement Lab, a Materials Measurement Lab. That is how we get the kilogram, the second, it gives us GPS and everything else. But we don't have a biomeasurement lab.

So that is an example of something, if you had not thought about it before, it is underneath the surface of things. Like whoever thinks about that? Well, that is because the ohm was figured out in the 19th century, and we depend on it now. So metrology would be an example.

Here is another thing. If you want to win, in anything in emerging tech, you have got to be smart and you have got to be hard working. But what is more important is the tools, the tools you have got for observing, making measurements, making models, computing, prototyping. So tools for making, modeling, and measuring, with enough biology, absolutely critical.

Why do we only have breakthroughs like CRISPR once every decade or so? That is bizarre. There is so much low-hanging fruit. The answer is because we are not laser-focused on how people spend time and money when they do biotech research. When our students do something, when our entrepreneurs do something, where does the time and money go? And if we

pay attention to that we could ask, huh, where are there opportunities for improving the tooling, ever-better tools for ever-better biotechnology.

The secret sauce of Silicon Valley is not all the things we consume, but it is the fact that it has got the critical mass tool developer ecosystem that makes ever-better tools for measuring, modeling, and making electrical systems. We need that critical mass engine running for biotechnology.

A specific recommendation then would be to create a national biotechnology accelerator, that is not doing biofields for the Department of Energy or biodefense for the DoD, but its only mission is to make better tools. These are all relatively tight, not too expensive packages that have unbelievable leverage and ROI.

VICE CHAIR SCHRIVER: Thank you. I am going to try to get a second question in here to Mr. Cheung. You described -- my words, not yours, but basically a combination of the run faster side and the thwart and export control side. And you mentioned the key role of allies. And I would suggest that reviewing our efforts on semiconductors have been pretty successful in getting allies to come along, although that group of countries that are involved in the true chokepoint is relatively small.

Are you aware of any discussions with allies and how willing they might be to cooperate on export controls in the area of robotics and other areas you addressed?

MR. CHEUNG: Thank you, Commissioner Schriver, for the question. I think it is a very good question. The point is I don't think you U.S. has ever initiated a very large-scale dedication or tried to have a bilateral negotiation with counterparts like Japan and Germany regarding the robotic development. Especially just three years ago, in 2022, Chinese, one of the biggest, largest industrial robot manufacturers, Midea Group. And this group is based in the Greater Bay Area, in Foshan.

Three years ago, this company, already the largest industrial robotic group in the world, purchased another Germany historic and leading group in terms of industrial robotics. And it is called KUKA AG. This company was funded in 1898, one of the most historical and world-leading automation and humanoid robotic companies. But then the Japanese government didn't ban it, and they just allowed it. They allowed the Chinese larger robotic company to purchase one of the historical state, symbolic companies in Germany, and in order to enhance the productivity and try to absorb the German engineering expertise for the Chinese.

So I feel like, I mean, especially for countries like Germany, we haven't seen any pattern that they are really trying to take this seriously and trying to align with U.S. export control or the grand economic statecraft strategy in order to contain the Chinese modernization progress in robotics AI.

However, I think Japan is a very different story. Japan has been traditionally a strong ally for the United States. I think there is a lot of leeway and leverage if the U.S. stopped negotiating with the Japanese counterpart. In terms of robotics exclusively, I think that the room is still likely, and I think there is a lot of room for them to collaborate. Because, as a matter of fact, actually the Chinese, when they conducted a net assessment, we have seen the Chinese have been making arguments about, like, they know that at the end of the day, Japanese contributes 90 percent of motors or very advanced robotic components. They know that if one day the Japanese tried to ban all the exports of these kinds of components and tried to follow and conform with the U.S. leadership, and then they would be doomed.

So that is why China, since years ago, has already started the domestic discussion about how to localize the supply chain, how to replace their reliance on Japanese components. They

haven't done that yet. They still rely on Japanese components somehow.

So before it is too late, I really highly recommend the U.S. government to talk to their Japanese counterparts on this matter.

VICE CHAIR SCHRIVER: Thank you. Sounds like a lot of work to do with both partners, but I appreciate you highlighting that.

Commissioner Kuiken.

COMMISSIONER KUIKEN: Thank you. First of all, excellent opening statements. I really appreciated all of them.

Mr. Cheung, Randy kind of took my question here. So talk to me about where the United States should think about making investments in terms of delivering military capability in the space that you sort of talk about.

MR. CHEUNG: Thank you so much. I would go back to my example regarding military drones. I mean, we all know that U.S. and Israel have been two of the largest military drone suppliers to the world. However, China is really catching up in recent years, and I don't think many people really discuss the two most advanced military drones, as mentioned, the Wing Loong and Rainbow series of Chinese military drones. Just last year, Chinese has sold more than 50 Wing Loong series military drones to Pakistan.

COMMISSIONER KUIKEN: Mr. Cheung, is it drones that we intend to invest in or the software that enables them?

MR. CHEUNG: I think it is a little bit of both. When we talk about drones, it is always about the hardware and software behind that. So, I mean, when we try to invest in military drones, it also includes the technology behind that and the software behind that.

One quick example is that China is still lagging behind the turboprop engine, but now, in their most advanced military drone they have just armed it with a turboprop engine which they actually recently perhaps purchased from the Germany counterpart.

So I would recommend that in order to develop this kind of technology to compete with Chine we need more stipend, we need more economic incentive for the industry. Because one of the strains for the Chinese military's drone is about the cost. So we need to ensure that the U.S. can provide affordable and also well performance military drones to your allies in order to ensure that the global military drone market is not only occupied by the Chinese counterpart.

COMMISSIONER KUIKEN: That is helpful. Thank you, Mr. Chung.

Dr. Endy, you talked about seat belts, computers, and semiconductors in your examples. If I am the Chinese government I am probably trying to think about military applications, as well. Obviously, semiconductors go on platforms and things like that, but what are the other sort of military applications, just to sort of unlock our thinking about biotech and the opportunities in that space, that undoubtedly Chinese researchers are thinking about?

DR. ENDY: Thank you, Commissioner Kuiken. You need to supply an army. What does an army need? So food, fuel, materials. I mentioned in passing the possibility of biosynthesis of energetics, so the supply chains for making the things that cause things to move around and go boom. That is not an example of a future biotechnology. That is a biotechnology that has emerged over the last decade. But anything to do with operating a military, and anything you can make genetically encoded can be manufactured through biology.

One of the interesting twists around this is that we are familiar with industrial supply chains, centralized manufacturing, big factories. Biology and nature are the opposite of that. The leaves on trees don't come from factories. They grow in place with the energy and materials that arrive where the tree is. So biology promises forward, if you will, manufacturing, or distributed

manufacturing.

There are other things that show up when you begin to do convergence of technologies. So you think about biology being fed with sunlight or sugar, but you can actually now imagine building with biology starting with electricity. So anywhere you could source electricity and then pull carbon out of the air, you run a type of electrobiosynthesis process. Again, general purpose. So anything you need that can be genetically encoded you could make.

This is all in support of operations, if you will. In my written testimony I have a mention of other possibilities, specifically related to biological weapons. My own view is we have all been blessed over the last 50 years to live in a world where there is no nation that brags publicly about having a biological weapons program, and we should do everything possible in partnership with Beijing and others to make sure that stays the same, absolutely.

But there is that other side. I don't want to go into that gratuitously, but just mention it in response to your question.

COMMISSIONER KUIKEN: I didn't run out of time, so Dr. Aboulafia, should the U.S. and Europe consider constraints on what is available, from a parts perspective, on China? You talked about the supply chain, how it is sort of reliant on U.S. and the Europeans predominantly right now. You got into this sort of jet engine piece. I think we saw this graphic in preparation for this hearing that sort of showed where everything comes from. It is probably your graphic. I would be interested in your views on whether or not the U.S. and Europeans should consider that.

MR. ABOULAFIA: Yes, thanks so much for that question, Commissioner. It is absolutely essential to consider what we give them, because obviously there is no intellectual property protection whatsoever.

Having said that, I think it is extremely important to keep China within the Western ecosystem's supply chain, because the alternative of having them completely decoupled would lead to a situation where we would have no leverage whatsoever about the evolution of their aviation business, and where other parties could simply go their own way. Like, for example, there is nothing that Europe couldn't provide everything, really. So I think it is important to have the U.S. with its presence somewhere in the supply chain for Chinese platforms.

I am also concerned about the idea of China completely just breaking away and achieving completely autarchy, which would be tremendously expensive in the aviation business and almost certainly guarantee second-rate products. But I think it would also lead to, well, frankly, just a lot less leverage over their evolution in terms of transportation policy, in terms of national defense, and everything like that.

But yes, I think it would be good to keep a close watch, and we already, to a certain extent, have this. Like for example, the U.S. has prohibited the export of certain products and technologies, when identified as being a concern from a dual-use perspective. I believe there was a helicopter engine. I seem to recall it was the China Z9 helicopter that required a Pratt & Whitney PT6 turboshaft -- this is about 10 years ago -- and we prohibited the export of that.

We also have the ability to basically just declare COMAC to be a military end user because of the nature of its ownership, via AVIC. And we have exercised that in the past. For example, their national turboprop transport, the MA700, is effectively now dead in the water because we have denied them the license for a PW150 turboprop engine. This happened about three years ago, I believe.

So I think we are doing a pretty good job. We should be doing, perhaps, just a little bit more, and of course, remaining vigilant in terms of, well, monitoring the system for cyber

espionage, because that has been a feature of the landscape, unfortunately. And as I am sure the Commission well knows, it is very difficult to keep the system completely secure, and it is important to maintain constant vigilance.

But in terms of the areas, I would mostly focus on avionics and all of the computation and whatever system that goes into -- displays, everything from weather radars and whatever else.

VICE CHAIR SCHRIVER: Thank you very much. We are going to continue with the questioning, and the Co-Chairs did not set a very good example when it comes to time management, so I am going to encourage my fellow Commissioners to do as we say, not as we did.

Commissioner Stivers.

COMMISSIONER STIVERS: Thank you, Commissioner Schriver. I guess that the Co-Chairs of the hearing have that ability to do that. But I will try not to go over my time.

Dr. Endy, thank you for focusing on the cost of time. Unfortunately, we have been having these same similar discussions on this strategic competition on emerging tech for years. We have seen a lot of progress in the private sector, not as much progress on U.S. policy, which I think, you know, from your testimony, has probably been modest, at best.

Are all of your conclusions today that -- correct me if I am wrong -- that we are losing ground, and if there isn't a course correction on U.S. policy in the next, you know, months and short term years, that we will be overtaken by China on these particular technologies?

DR. ENDY: Commissioner Stivers, yes.

COMMISSIONER STIVERS: Mr. Cheung, is that your conclusion?

MR. CHEUNG: Yes. That is my conclusion, yeah, and I am welcome to your other questions.

COMMISSIONER STIVERS: Okay. Mr. Aboulafia?

MR. ABOULAFIA: Sorry. Yes, I concur.

COMMISSIONER STIVERS: Okay. Thanks. I just wanted to get that as a very clear takeaway from this hearing.

Dr. Endy, in your written testimony you talked about the BIOSECURE Act. Can you comment on your view on that bill, and if there are things that can be done to improve that legislation in the new Congress?

DR. ENDY: It is a defensive crouch. You don't win a race by crouching. And so our every instinct, as we have experienced China's ascendency in emerging biotechnologies and real biotechnology has been to try and hit the stop button. And everybody understands why we want to do that, and sometimes you have to do that. But if you only hit the brake pedal and you are trying to win a race, you are going to lose. We need to learn how to push the go pedal as hard and as smartly as possible.

So I don't really want to get lost in the BIOSECURE Act, because although it is well intended, it is not law, and it is not law because our pharmaceutical industry, domestically, has an overwhelming dependence on the contract research organizations that offer these services. And it is not obvious that you could instantly disentangle it without causing our domestic innovation framework in pharma go to go zero, or near zero.

So it is a tough situation, and as I mentioned in the written testimony, imagine if it was the same for information technology. Imagine if our IT layers were only supported by cloud computing services and capacities that were operated in China. Like we would never get into that situation. But somehow we have gotten into that situation in biotech, and it is like normal?

So a lot to talk about, but just recognize that the BIOSECURE Act, well intended and important, isn't going to get us to victory.

COMMISSIONER STIVERS: Thanks for that. Mr. Cheung, you have written a lot about China's Greater Bay Area Initiative, which is basically Beijing's effort to economically and socially integrate Hong Kong with Mainland China. Can you talk about the Greater Bay Area Initiative and its role in the technologies you talked about in your testimony, but also I know you have a greater knowledge of these issues, and why we should be concerned about its role in Made in China 2025.

MR. CHEUNG: Thank you so much for the question. A little bit context regarding the Greater Bay Area Initiative scheme. So the Greater Bay Area, for the past four decades, has been the largest regional economy for China, and contributing almost one-third of the Chinese GDP there. And the GBA region alone, actually, the GDP has surpassed South Korea in terms of GDP scale.

And in terms of the industrial robotics, more than like 44 percent of the industrial robotics is generated and created in Greater Bay Area, and that's why GBA has been one of the national initiatives promoted by Xi Jinping.

And GBA has a lot of advantages. First of all, they have Shenzhen, the DJI headquarters there, and they have Hong Kong and Macau. Hong Kong is an international financial hub. And not many people know that actually Hong Kong is the second-largest IPO center for biosecurity, so a lot of bio companies, pharmaceutical companies go to Hong Kong to seek funding.

So with this context we recognize that, I mean, actually GBA has an important role for the MIC 2025. And then we also see that how Shenzhen, Hong Kong, and other Guangdong Province policy have been promoting MIC2025 schemes and goals in terms of funding, in terms of state regulations, and tried to put more incentive to allow medium-sized companies or unicorn companies or large tech giants in Shenzhen in order to compete with their Western counterparts.

COMMISSIONER STIVERS: Thank you.

VICE CHAIR SCHRIVER: Commissioner Sims, welcome in from the great state of Alabama.

COMMISSIONER SIMS: Thank you. Roll Tide. So we talk a lot in this Commission, in these hearings, about competition between the U.S. and China. It is an economic competition. It is a technology competition. It is a military competition. But at its most foundational level, it is a competition of systems.

So I would be curious to hear from each of you in the areas where you focus, how do you see the strengths and weaknesses of the two systems playing out? And I will say no one is going to accuse you if you say the Chinese have an advantage in this way or the other by virtue of their authoritarian system, that you are advocating for that system, but how do you see that playing out in your areas of expertise? Maybe we will start with you, Dr. Endy.

DR. ENDY: Yeah, the ship of state. If you are lost at sea who makes the decision where to go -- the captain, the navigator, or a vote of the crew? It depends. So, you know, ways of working that allow for crisp decision-making can get things to happen sooner and faster and risk bigger mistakes. Democracies are harder to get organized and underway.

When that maps to biotechnology, what do you see? It is why, for example, I like to highlight food security as it relates to China. Last time I was in Beijing I was having dinner with the Agricultural Minister. His concern and surprise was that China had enough food and water. That is an advantage for China as they seek to advance biotechnology. There is an urgency there that we don't feel in the same way in the United States. Yes, we care about food, quite a lot, but

not as intensely.

Then it is going to come down to other factors. How quickly is the world changing? If things start to change more quickly we are going to need to deploy biotechnologies more quickly. Climate-resilient crops -- what happens if you simply cannot grow things where we used to grow them because the temperature is different or the salinity in the soil is different? How do you adapt crops to survive fast enough?

It is not that we can't do it, and historically we have done it over and over again in the United States. But for the United States to work well, what I have observed is we need to have a positive, aspirational message. We did this when we went to the moon.

The thing about biotechnology that is different than Apollo, though, the Earth only has one moon, one place to go. Biotechnology has got a million places to go. How would Apollo have been different if we had a million moons orbiting the planet? We would have done things like SpaceX a lot sooner because there are so many places to go.

And so, you know, there are some advantages in China because they can move faster, and that is coupled to their high-level needs. We can do the same, but to unlock our superpower we need to have that shared aspirational vision for why it matters.

COMMISSIONER SIMS: Thanks. Mr. Cheung?

MR. CHEUNG: Thank you for the question. I think this is a very important question. I concur with the view that the modern era technological competition is a competition of ecosystems, and China is doing so remarkably well. For example, in terms of robotic developments, as mentioned, we have heard of the Unitree, and then I think just a month ago, Huawei see that Unitree is really excelling in robotics. And now they recruited Unitree to become the only supplier of future Huawei robotic developments.

And at the same time, Huawei has innovated their own home domestic operating system called Harmony OS. This is similar to the iOS system. And this Harmony OS system is being exported to all major robotic companies in China right now, more than 10 Top Ten companies right now, because they believe that in terms of to ensure the operating system of robotic AI to be smooth and not relying on Western technology, Huawei has to support that. And Huawei has been doing that.

And also, at the same time, when we talk about another robotic tech giant in China, it is called UBTECH. And this company has been working closely with BYD, the largest EV company in China, to work together to provide industrial robotics, robotic arms, to ensure that BYD can produce EV as a very efficient way in order to ensure that BYD can also become the giant in their own industry and to compete with the rest.

So we see that despite all the state-sponsored and subsidized initiative we have been talking about. Actually, the ecosystem itself, companies behind them, also support each other and form a very strong ecosystem.

COMMISSIONER SIMS: Mr. Aboulafia, maybe just 15 seconds, if you have got a short thought on it.

MR. ABOULAFIA: Yeah, thanks for the question, Commissioner Sims. I think there are some big differences, of course. You know, there is no diversion of resources. This is a single-minded focus. There is no focus on returning cash to shareholders. It is just let's develop a national aircraft industry. That is an impressive advantage.

However, the advantages of an open system, where you can cooperate with other countries and you can innovate while providing intellectual property protection to your partners around the world, make sure you get best-in-breed systems and technologies in new platforms is,

I would think, an overwhelming advantage for the West.

COMMISSIONER SIMS: Thank you all.

VICE CHAIR SCHRIVER: Madam Chair, Commissioner Price.

CHAIR PRICE: Thank you, and thank you all for participating today. This has been very, very enlightening in several areas.

Dr. Endy, I want to go back to the cost of time. I am very taken with this. You specifically said we have less than 1,000 days. That is a startling way to get the point across. Can you expand on why you picked that number?

DR. ENDY: One of the objectives in the 2012 strategy for synthetic biology was the construction of a cell from scratch. When I am in Washington I get asked what type of cell are we talking about. Is it a bacteria, or a yeast, or something? And my favorite answer is, "It's an American cell." And what I mean by that is UNIX was an American operating system made in New Jersey. Whichever nation is the first to realize some of these foundational advances that are at the core of bioengineering will have an advantage in perpetuity. These are coordination solutions that just change the game.

Remember that 2012 strategy. Well, this goal of building a cell from scratch, it is on the 2032 deadline, 20 years out from 2012. We are ahead of schedule. So something like that is going to be true within the next 1,000 days. Is it going to happen here or somewhere else? Should it be in cooperation, should it be multilateral, or otherwise?

In other words, there are a number of these achievement which are effective coordination solutions that are winner-take-all accomplishments, and if we don't get them we just lose that in perpetuity. You know, where do you go for search? You are going to go to Google. Where do you go to law school? If you can, you are going to go to Yale. Where do you go? Where do you go? Once those answers get into place, it is hard to change them.

So that is what is right in front of us with biotech, and if we miss it, we miss it. The window is down.

CHAIR PRICE: Thank you. You also, in your written testimony, talk about 90 percent of raw ingredients for antibiotics come from China. Can you talk a minute about that more, and is that something we watched happen, and what forces made us get to that place?

DR. ENDY: We talk about a lot the supply chain dependencies for computer chips. The same is true for essential medicines and many other things that are made by biology. China is very good at biomanufacturing. We are good at biomanufacturing in the United States for a few things, such as biofuels, but we don't have a surplus of fermentation capacity in this country. So when innovators want to figure out how to bring their product to scale -- I am not talking pilot scale; I am talking full-scale manufacturing -- what we are finding is they simply can't find the factories or facilities here domestically.

In contrast, when you have an all-of-nation approach to biotechnology, you are seeing significant capital investments in 21st century biomanufacturing, farms effectively, with holistic site engineering, access to cheap power, access to wastewater treatment, all the things you have to do to make this work. So it simply becomes easier in an open market to get better access to efficient capital by doing manufacturing overseas. It is the same playbook you have seen in batteries, solar panels, you name it, and it just happens to land on things we care about that are made by biology, like antibiotics.

CHAIR PRICE: Thank you. To Mr. Aboulafia -- I hope I got that right -- and Mr. Cheung, we spend a lot of time talking about economic stresses that are happening in China right now. Can you talk about if there has been any impact on the sectors you have addressed, in

particular, Mr. Aboulafia, maybe we will start with you.

MR. ABOULAFIA: Thanks, Commissioner Price. So far, no. You know, we monitor air travel demand very closely, and it has made a pretty strong comeback after a few stumbles, relative to where things were before the pandemic. And, of course, it is that desire to have self-sufficiency to transport people within and without the country that is driving these jetliner developments. So as long as air travel demand growth remains robust, they are going to pursue development of these aircraft.

Similarly, you have seen a strong comeback in the number of imported jets. At one point, 2018 I believe, they took about 350 Western jets, representing roughly 22 to 23 percent of global jetliner output, from Airbus and Boeing. Then it effectively collapsed as a consequence of the pandemic, along with geopolitical tensions between China and the West. It is making a good comeback. It is about, I believe, at 160, 170 jets last year.

So that, I think, also speaks to their desire for a home-grown solution that replaces those aircraft, and we have seen no evidence of a diversion of resources away from their aerospace development priorities as a consequence.

CHAIR PRICE: Okay. Go ahead and answer.

MR. CHEUNG: Sure. Thank you for the question. A very short reply is that despite all the economic hardship and then the aging population, all these kinds of problems, the Chinese industrial robotic production actually has been increasing. I think one of the major reasons that Chinese government has been putting a lot of investment, as mentioned, from states and national level, and at the same time they also ensure that their very own production, their innovation, the robotic arms, for example, can actually help them to further increase the production.

So when we talk about productivity in terms of the robotic industry, China is doing really well in this domain.

CHAIR PRICE: Thank you so much.

VICE CHAIR SCHRIVER: Thank you. Commissioner Miller.

COMMISSIONER MILLER: Thank you. Thank you, Chair Schriver.

Mr. Aboulafia, unlike many of these sectors that we are assessing today, the aviation sector seems to be something of a success story. Industry relies on relatively few direct inputs from Chinese suppliers. U.S. companies haven't transferred their tech in return for market access to the PRC. The sanctions regime, in this case the military end user list, has been applied and appears to have some teeth.

From this can you apply any broader lesson to U.S. efforts to sensibly manage competition in other sectors, like semiconductors?

MR. ABOULAFIA: Well, thanks very much for your question, Commissioner Miller. You know, I don't want to move too far out of my swim lane but it seems that there are some interesting lessons that could be drawn. For one, I tend to think that because of the success we have seen in managing the West's response to China's aspirations in the jetliner business it is perhaps important to be mindful that decoupling is perhaps not the best idea. A total and complete break is perhaps not the most productive solution, because they have tremendous resources, and obviously anything that keeps them within the fold, anything that keeps them at the point where we could conceivably cut off key technologies is to our advantage, frankly.

I think it is also just very important to be mindful of three possible ways of working with them. One is an absolute no, we will not give you this access to this technology. Another is we will give you access to this technology and make it available in such a way that the technology will be shared, and obviously you need to keep a very close eye on what technology and how

accessible it is to them, because, of course, they are going to copy it and create a homegrown solution. We have seen this with countless components and systems and technologies in the aviation business.

And the third is, you know, we like supplying you. We like having a level of control on your supply chain. But we are not going to participate in any kind of joint venture or future technology development. So we keep it protected, even encrypted, and it gets delivered in a large box, and you can use that system, but you have no access to the architecture of that system.

So those are the three buckets I would view exports in cooperation on a technological level with China.

COMMISSIONER MILLER: Thank you. I would like to ask each panelist for a brief response to the following question, for the record. How would you best characterize U.S. export controls on key technologies in the area or areas of your expertise -- absolutely critical, useful, not important, or counterproductive?

We can start with Dr. Endy.

And keep in mind this is not to say only export controls. Export controls as a component of a strategy.

DR. ENDY: Well-intended, good luck.

MR. CHEUNG: I think it is useful in terms of robotic supply chains.

MR. ABOULAFIA: I regret it is absolutely critical given the dual-use nature of many aerospace technologies and components.

COMMISSIONER MILLER: Mr. Cheung, back to you. Take us to the battlefield for a moment. We have seen a lot of pictures of robot dogs shooting lasers out of their tails. You know, you can imagine terminator machines. But most of the conversations we have suggest that the robotics we need to be worried about on the battlefield are not that. It is certainly drones, underwater drones and air drones, other things.

What should the military, in particular, be most focused on in terms of the robotics area, in terms of battlefield concerns in the future?

MR. CHEUNG: I mean, China is already leading in military drones in terms of production and also the creativity they have been using. They have just recently, two months ago, innovate another drone model ship in Zhuhai air exhibition festival. And in this, I mean, air drone model ship, they have been really showcasing a lot of capabilities that the U.S. currently does not have.

But at the same time I want to go back to your robotic dog question. I don't think this is a very futuristic question because also in the same exhibition, in the exhibition in Zhuhai, for the first time they showcased more than one robotic dog. Actually, the PLA media called it "robotic wolverine," because only wolf can actually move that, I mean, at scale and at the same time to mobilize them together. And each robotic dog actually is equipped with ground-to-ground missile and also other types of weapons.

So, for example, in this scenario I would say the U.S. government should also be aware of the situation and try to do more in order to counter this kind of developments, both in air and on the ground and also on the sea.

COMMISSIONER MILLER: Thank you.

VICE CHAIR SCHRIVER: Thank you. Commissioner Goodwin.

COMMISSIONER GOODWIN: Thank you, Mr. Chairman. And let me join my colleagues in extending my appreciation to the panel for all their hard work and their testimony today.

Dr. Endy, in response to Commissioner Price's question you indicated that the first to adopt some of these foundational technologies will have an advantage in perpetuity. And I want to explore that a little bit with regard to this notion of a diffusion deficit, which you, I am sure, have heard some scholars talk about, to refer to the gap between the country's ability to adopt new-to-the-world innovations and the corresponding ability to diffuse, distribute, and have those innovations and inventions adopted at scale.

Viewed through that prism and that notion, some of the traditional metrics for measuring innovation and innovation capacity, like patents, R&D spending, and publications don't provide the whole picture, and instead the talent pool, workforce investment, and the market itself may be better indicators.

I wanted to get a sense from you as to this notion of the diffusion deficit with regard to the biotech sector, and both in China and in the United States, and what impact, if at all, you think it would have on the advancement and deployment of biotech innovations.

DR. ENDY: Mr. Goodwin, thank you for your question. It is a good question. You know, to reflect a little bit as an educator, our number one job when we are in the classroom is to inspire the student to do the hard work of learning, and if you can do that then you have the same diffusion issue in the classroom, if you will.

It is why I was trying to focus some of my remarks on how inspired the Chinese people have become about biotechnology, and not just the students -- all through the stack. If you look at the reports coming out of the JPMorgan Conference, when people are now visiting China, looking to do acquisition of pharmaceutical innovations, what they are encountering is people who are completely enthused and energized to make this real. So I don't see any diffusion limitation on uptake in biotech innovation in China.

The puzzle we have got in the United States, frankly, is we still don't really think about biology as a technology. We think about electronics as a technology. You know, the reason we didn't hit the go button in 2012, when we had the strategy in hand that others adopted, was because of concerns around GMO foods.

And so I actually think we have got a greater diffusion challenge round biotech domestically, because we haven't quite figured out how to explain it as a technology that people could fall in love with.

COMMISSIONER GOODWIN: So from your perspective, you don't see any challenges with regard to the education system in China or workforce development there that would inhibit their ability to deploy these biotech advancements. --

DR. ENDY: No, and thank you again, Commissioner. No, I do not, and I would additionally note that they have other advantages still. So, for example, if you want to make stuff at scale, you have got to manufacture, you need process engineering, you need chemical engineers who know how to do this stuff. We grew up, in this nation, learning how to do all of that stuff, starting with petroleum. The entire skill set needs to be applied for biomanufacturing. But our training and workforce around biomanufacturing and the places where we would do that sort of education and training has eroded. So I would say, again, we are disadvantaged domestically.

COMMISSIONER GOODWIN: Thank you.

Mr. Cheung, in your recommendations to create a new committee on robotics one of the things you would have them focus on would be to map supply chains to identify vulnerabilities and dependencies. A couple of years ago, we actually made a recommendation to create a centralized office that would help map supply chains across the board, across sectors, and across

government agencies. And the benefits of such centralization are fairly obvious -- avoiding silos, hopefully enhancing coordination, and the like.

The challenge, I think, as we acknowledged at the time, is so much of the critical know-how and expertise is supply chain specific, industry and sector specific, and even product specific. So how do you square that circle? Do you think robotics is a sector where specialized, dedicated, exclusive supply chain mapping would be more beneficial?

MR. CHEUNG: Thank you, Commissioner, for your question. I would say that, first of all, we have to, on the same page, on something, for example, where is the end game of AI? If we believe that the ultimate form of AI is in the physical world, then we see the necessity to establish this kind of task force and commission to study the supply chain.

And then, regarding the supply chain, I would say, I mean, working within robots there are just so many critical components in terms of the motion control model and the operating system, and even the robotic arm.

So I think the U.S. is leading in some ways, but the Chinese are also leading in other ways. So that is why I think this kind of very exclusive task force is very critical to understand what is the ecosystem now, and then which area is U.S. leading, and which area, actually perhaps it is Japan or Germany leading, and whether or not the U.S. government should actually actively collaborate with their counterpart in order to ensure that U.S. has the most secure access to this robotic component.

So I would say that all kinds of, especially at this very early development stage, many components are still very crucial and essential. So that is why we have to study that advance.

COMMISSIONER GOODWIN: Thank you.

VICE CHAIR SCHRIVER: Thank you. Joining us virtually from the great state of New Jersey, Commissioner Friedberg.

COMMISSIONER FRIEDBERG: Thank you very much and thanks to all of our witnesses.

Mr. Aboulafia, if I could start with you. Aviation seems to be -- it is an interesting area because it is one in which China evidently had a priority for some time, developing a commercial airliner. And they have been trying but they seem not to have been able to do it.

Could you explain why that is so, and in particular, I wanted to ask you about two possibilities. Is it the case that this is just a very complicated and difficult problem and everybody has difficulty doing it? Is it because there are only two companies in the world that are capable of doing it, and they have an incentive to control the diffusion of the relevant technologies themselves? Is it both? Is it something else? Why is it so hard?

MR. ABOULAFIA: Yeah, thanks for the question, Commissioner Friedberg. It is really the heart of the matter, isn't it?

I think there are a couple of things. For one, just intrinsically the barriers to entry in this business are just exceedingly high. Another is that you have got to consider the economics, the nature of the user community. There are a lot of, like military products, you can be within 5 percent in terms of performance and maybe it really doesn't matter. You might take a few more casualties, but still your military power is your military power. And consumer goods, it comes down to sticker price, features, you know, cars, whatever else.

Aviation is different because the user community has extremely thin profit margins and a great deal of competition, which means if you have a product that is 5 percent inferior it means your competitor can out-price and out-profit you -- you really shouldn't be in the business. So there is that.

The other is the fundamental nature of China's approach to this business. You have got one of the biggest markets in the world, biggest single export market in the world. You have got tremendous talent. You have got tremendous resources. I would argue that the only thing they could do to mess up this rather promising proposition is what they are doing, which is to create state-owned enterprises that mandate technology transfer and provide no intellectual property protection.

That guarantees that people are going to show up, you know, without any input from Airbus and Boeing. They are just naturally going to pull back and protect their IP. So you have got a lot of folks showing up for these joint ventures with systems saying, "Well, here is our latest invest as of 1996."

And I think that explains why, while the 909 is one of the worst jets ever built, and why the 919 is just a notch behind the A320NEO and 737MAX in terms of performance capabilities. If they were to change that approach, and become, say, like a proper integrator of input systems, like an Airbus, a Boeing, or Embraer, they would probably be very good. The great irony here is the only thing that they could do to mess up a very promising picture is kind of what they are doing.

COMMISSIONER FRIEDBERG: All of your comments, if I understand you correctly, have been about the commercial aviation business and China's difficulties in developing engines, in particular, for commercial jets. What about the military sector, and can you comment on the quality of China's military jet engines?

MR. ABOULAFIA: Yes. Thank you. You know, this is an area where they have made tremendous improvement. For many years they were wedded to Russian engines, and the Russians, of course, as an outgrowth of the old Soviet Union military industrial complex, produced a decent engine. Again, you can be within 5 or 10 percent in terms of reliability, in terms of fuel burn, and it only shows up in slightly higher casualty numbers. Tragic, but not the same as, you know, why bother, as in the airline business.

However, the Russians were getting a bit wise to this and prohibiting exports of engines and saying, "Well, you have to buy our fighter jets. We are really annoyed at you for creating your own fighter jet industry," which they have done.

So they have gone down the path of creating their own jet engine industry for military products with the WS-10, WS-20, and other engines, and they have done pretty well. I would argue they are getting very close, if not at the level of Russia's military engine capabilities.

That doesn't necessarily, at all, translate to success in the -- given the white-hot competition associated with commercial jet engines. Far from it. There are many countries, like France, for example, that do a good military engine but can't seem to do a commercial jet engine, except as part of a joint venture or something. So they have made progress.

COMMISSIONER FRIEDBERG: Thank you. I think I am out of time, but if we have a second round I have some more questions. Thank you.

VICE CHAIR SCHRIVER: Yeah, I think we will, Commissioner Friedberg.

Welcome again, Commissioner Brands.

COMMISSIONER BRANDS: Thank you. Dr. Endy, I wonder if we could come back to "well-intended but good luck." It strikes me that the conventional wisdom around a lot of these critical technology sectors is that you need a two-part framework for success, promoting your own innovation and perhaps restricting the other side's. Are you skeptical about the restrict part of that framework as a general matter in the biotech area, or is it a question of doing something other than export controls and the things that have been proposed so far?

DR. ENDY: Thank you, Commissioner Brands. I would just point out some of the unique characteristics of living systems. They are capable of growing and reproducing. The tools of synthetic biology allow for interconvertibility between the realm of the physical and the realm of the digital. So you can take physical biology, sequence the DNA, you can have a digital representation of the code, and you can download and grow if you could remake the DNA.

So we have got a situation where we have got reproducing machines that can be digitally encoded and transmitted around the internet. So maybe some of the lessons that would be good to look into and draw upon, outside of my lane, would be in software and how we govern control of software while promoting its development.

But those are some of the structural challenges that underlie how you might want to think about being mindful stewards of the fusion and proliferation in biotech, specifically.

COMMISSIONER BRANDS: So a second question for you. You said in your written statement, and a little bit in response to another question, that the U.S. and China should find common ground and creative approaches to strengthen their opposition to biological weapons. Could you say a little bit more about what that looks like and what its feasibility would be in the context of a pretty fierce technological competition?

DR. ENDY: Yeah. Let me give you an example. I serve on the commission that advises on variola virus research. Variola is smallpox. Smallpox killed more people in the last century than all wars combined, hundreds of millions of people. Research with smallpox is governed by a multilateral committee. We oversee the work in Novosibirsk, at VECTOR, and at CDC in Atlanta. What will happen to that committee is a little bit up in the air right now, but never mind that.

You know, even in a context where you have Chinese, Russian, and American and other scientists tackling a very tricky and dangerous topic, we can figure out how to work that together.

I will give you another thing, just as a quick example. How many times have any of us wondered, or even asked ourselves, where did SARS-CCoV-2 come from? It is a good question. Here is a better question. Why have we made it so hard to answer that question, and what could we do to make it easier to answer questions like that? The answer becomes, again, a type of cooperation, multilateral frameworks that don't establish trust but get rid of some types of distrust, so it just becomes easier. Thank you.

COMMISSIONER BRANDS: Mr. Cheung, one of your recommendations was to consider creating a dedicated open source intelligence agency, which strikes me as a good idea, in general. But I wonder if you could say a little bit more about why it would be so particularly useful in this specific context.

MR. CHEUNG: Absolutely. Thank you for the question, Commissioner. I would say that, I mean, the very first reason is that because I am now working at a think tank based on open source intelligence. And I do see the merits of that because I think, generally speaking, Westerners are not aware how many information is still publicly available or even commercially available online, on different kinds of Chinese platforms.

So when you have this kind of OSINT agency, to dedicate them to looking to the Chinese website platform, and you can find a lot of useful information in order to compile a report or any useful details, especially about a supply chain of China. So I think this is a very important skill set. And sometimes it is way beyond, I mean, just hiring a bunch of people who understand or speak Chinese. You also need the context, right. Where to go to find your best Chinese source of platform? Where to go? Go to Baidu or go to Weibo or other Chinese platform.

So you need the social context for that. So you don't just hire a bunch of people who just learned Chinese, but you need a dedicated, exclusive agency and people who understand the Chinese social context, hire them in order to allow them to work on this very dedicated and very sophisticated work.

COMMISSIONER BRANDS: Thank you.

VICE CHAIR SCHRIVER: We are going to move to a second round if Commissioners have more questions they would like to ask. And so far I have Co-Chair and Commissioner Kuiken and Commissioner Friedberg, I believe. Commissioner Kuiken.

COMMISSIONER KUIKEN: Thank you, Commissioner Schriver. Dr. Endy, there was this report on the Pacific Northwest National Lab website maybe three or months ago about how a group of researchers had basically shown up on every continent in the world, stuck a shovel in the ground, put it in a bag, and brought it back and sequence everything they found in there. The policy circles around D.C. there is this idea now about sequencing everything, and there is some magical advantage to that.

I recently had someone tell me about how the Chinese government is building sort of a belt, almost, of labs around various parts of Southeast Asia. I, obviously, have no idea of the consequences of this, but can you just sort of give us a sense of what that might mean? That is the first question. I am just going to give you all of them at once.

Convergence, everyone in D.C. talks about convergence of AI with, you know, insert the technology. You briefly talked about convergence of AI and biotech. Can you just sort of unlock our minds here in terms of do I just need to go on ChatGPT and put in some DNA code and I am magically going to have a biological weapon or a computer you talked about, or some other magical device?

And then to Commissioner Price's question about the 1,000 days, you gave a great answer. Boil it down for me. What policy do I need to do, and how much is it going to cost me. It is always helpful to sort of make things a little more crisp on the edges.

Sorry for all the questions. The time is over to you.

DR. ENDY: Thank you, Commissioner Kuiken, for your three questions.

Sequence everything. Just quickly two ways to think about it. Biology already exists. It has operated on this planet for quite a while, and it has got incredibly creative solutions. And so how do we learn what they are? Well, have to read it out. We have to sequence it. So if you go around and find biology and read it out it gives you a chance to make sense of it, to decode it, to read the book of life, so to speak. So that is where this starts.

Sequencing is a relatively new technology at scale. Twenty-plus years ago we had just barely sequenced ourselves, the human, for the first time, but now it is routinized, and the biggest sequencing factories are in Shenzhen.

So what about sequencing everything? You know, if you trained ChatGPT on English, you are feeding it in English, and then it comes out and gives you something that generates new language. But you could train a large language model on DNA sequences. And the A's, T's, C's, and G's go into the software and it learns how to compose A's, T's, C's, and G's.

You want to train that on good writing, but the good writing comes from nature. And so if you sequence everything you have that fuel or data stream that lets us have world-class training of the bio LLMs. So that is number one.

Number two, remember when that Cold War thing started, and suddenly we were worried about what might be happening on the other side of the Iron Curtain, and we needed to develop ways of seeing -- planes with cameras, and then satellites, and so on, GEOINT.

The same thing is happening in bio. If you want to have biosecurity you need to have BIOINT. And one of the ways that you could get to BIOINT is to sequence things, as a start. You want to do other things, too, but just imagine you know what is happening in biology because you are sequencing what is going on. So a nucleic acid observatory is part of a BIOINT consortium. It is one of the recommendations in the written testimony.

Convergence in biotechnology. There is really convergence with two big domains. I think about is joule fit in atoms, so energy and data and digital, including AI, and then bio is the atom stuff.

I mentioned in passing the convergence of energy and bio, electrobiosynthesis. If you want to follow a lead on that think about what China is doing with solar panel manufacturing and the idea that scaled photovoltaics could actually be used to grow biology when and where we need it.

And then on the AI side, sure, we need to use computing to figure out what the biology is doing and to generate new prototypes. But the important thing is it is not that AI is some magical tool that solves biology, which a lot of people seem to represent. That is wrong. We actually need to understand biology as a physical system, which is why it is so critical to get better tools for measuring biology, and modeling biology with physics, not just LLMs, physics base modeling. So flagging that.

Remind me your last question, really quick.

COMMISSIONER KUIKEN: A thousand days. Is it policy? Is it money? Is it both? Give me some concrete things to do.

DR. ENDY: Yeah. You know, the things I mentioned in response to Commissioner Schriver's question are just fine. Like what would it take to get a BML going a NIST? About a quarter billion dollars a year. What would it take to get three national biotechnology accelerators in the United States? $150 million a year. What would it take to do a 1,000-day sprint to build a cell? Less than $100 million.

These fit neatly within our existing agencies and portfolios. The issue is everybody is overdriven by the Congress to cure some disease right now, which is well intended but misses the mark. So it is like we could have so much higher leverage around our public treasure if we simply thought smartly around where are the high-leverage results.

VICE CHAIR SCHRIVER: Thank you. Commissioner Friedberg, did you want the second round?

COMMISSIONER FRIEDBERG: Yes, if you don't mind. Dr. Endy, I had a couple of quick questions for you. One of the things you mentioned was the importance of education. Do you happen to have any measure of the adequacy of the, for lack of a better term, the biotech workforce in the United States? Are we training enough people at the right levels? How does it compare to what China is doing?

DR. ENDY: Very quickly, domestically I think we do a good job. Where the shortage appears to be is in biomanufacturing, process engineering, all those things needed to operate at scale and supply the market. And then we have a whole bunch of challenges on the front end around the innovation ecosystem because of the boom-bust cycle, and, frankly, there are a lot of people looking for jobs in terms of biotech R&D right now, especially in pharma, and especially as it looks like increasingly that innovation is going to happen overseas. So that is sort of two things I would highlight domestically.

Things seem to be well staffed in China, and would want to follow up and get a little bit more data just to confirm every nook and cranny of that.

COMMISSIONER FRIEDBERG: I wanted to make sure I understood the comment that you made about American industry's objections to the BIOSECURE Act, if I understand your testimony correctly. What exactly is it that American companies depend on Chinese counterparts for?

DR. ENDY: If you take an example like WuXi and their service offerings, it is everything from building DNA, building cell lines, making measurements, setting up analytical chemistry processes, setting up the standards around that so that when you need to go in for drug approval at FDA they believe your data. And so on, and so on, and so on, and so on.

So all the measurements and the professionalization of measurements and the prototyping, it is all that type of stuff, but just with genetic and living materials as opposed to hardware or software.

COMMISSIONER FRIEDBERG: And does that dependence have an impact on the relative innovative capacity of American companies versus their Chinese counterparts? Are they being held back in some way by this dependency?

DR. ENDY: Yeah, that is a great question, Commissioner. Thank you for framing it that way. In the immediate term it doesn't feel like it, but you are basically getting hooked on somebody else's tooling. So what happens over a longer period of time is because you are distant from the tooling, you don't have that as sophisticated understanding for what can be done and what can't be done and how to really make sense of what the results are. So there is a risk that appears over time.

The only thing I don't yet have an opinion on is to think a little bit more carefully about the emergency of fabless semiconductor industry, where over a period of time, as silicon matured, you saw very innovative companies not having to own the low-level manufacturing and validation capacities.

COMMISSIONER FRIEDBERG: Thank you.

VICE CHAIR SCHRIVER: Commissioner Sims.

COMMISSIONER SIMS: I have one more question for you, Dr. Endy. In 2020, the Director of National Intelligence talked about the Chinese using CRISPR or similar technology to essentially create what he described as "super soldiers." And this kind of sparked conversations around ethnical boundaries and maybe what things the Chinese are doing, or would be willing to do, that get outside of the ethical constraints that we would have here in the United States but could potentially give them an advantage in some way.

Are you seeing things like that, and if so, in what areas?

DR. ENDY: I think germline engineering of the human for super soldiers or otherwise has been carefully scrutinized and studied, and in many respects denounced within the United States and China. We could get into the examples of what happened around some specific cases.

What I think is more relevant to your question is thinking about other ways of changing people without changing our DNA. So we are more than just our own cells and DNA. We are basically an ecosystem. We have microbes that live on our skin and inside us, the so-called microbiome. And making changes in those aspects of how we exist and operate seem likely to not fall into the same ethnical category, typically, and allow for much quicker changing and prototyping. For example, there are microbes that live in our guts that emit molecules that change how our brains work, and so on and so forth.

So I would point us to think carefully about other aspects of the human that are beyond the human, and the other parts of us that are easy to operate with and change. That is where it seems like there is going to be more innovation and more competition, potentially.

COMMISSIONER SIMS: So right now you are not seeing areas where they are pushing the ethical boundaries in a way that might give them an advantage?

DR. ENDY: Not as it relates to the human genome, no.

COMMISSIONER SIMS: And things not related to the human genome?

DR. ENDY: Yeah, not that I would mention here.

COMMISSIONER SIMS: Okay. Fair enough. Thanks.

VICE CHAIR SCHRIVER: Madam Chair?

COMMISSIONER PRICE: Thank you. I was just looking over some of the recommendations before we finish the panel, and Mr. Aboulafia, if you could just clarify one piece you have. You said, in your third recommendations, to ensure the U.S. jetliner industry remains competitive in world markets. Do you have a concern there that we are not staying in that direction?

MR. ABOULAFIA: Yes, thank you, Madam Chair. I do, indeed, have that concern for a few reasons. One, as you might have seen, unfortunately, in the headlines over the past few years, Boeing has been stumbling, and its execution and performance both keeping up the cadence of new technology development and in building its existing jets. There is some improvement in the past, say, six months or so, but the track record of the past few years has not been good. And, of course, for the broader American aerospace industry we need a healthy Boeing, of course. They are the most important commercial aviation company by a wide margin. So that is an area of concern.

Also their ability to access the China market has been, for political reasons, a little bit compromised. There are signs of improvement here too, but for a couple of years Airbus went from 50 percent to basically 90 percent. That is a concern.

And then, finally, there is the issue of managing China's rise. So far it has been a very, very slow road, and there are areas of concern about how quickly they could move down this road. But nevertheless, there is no question that they want in on this industry, and who knows what the next 10, 15, 20 years could bring, and what are the implications of that for the competitiveness of the Western civil aircraft industry.

COMMISSIONER PRICE: Thank you. And quickly to Mr. Cheung, I could not listen and reread some of your recommendations at the same time, so let me just give you a softball. Anything you listed in your recommendations that we have not already covered, that you want the opportunity to put on the top of our agenda? Then I would ask Dr. Endy the same thing. I think we got through most of yours, though.

MR. CHEUNG: Thank you so much. I think I would like to emphasize that, I mean, the collaboration between the U.S. and its allies is very much important. I am not just talking about the basic R&D program but we have to try to think how do we reindustrialize American enterprises and the industrial base and also try to perhaps work with allies to ensure that we have the productivity we want during emergencies. Because right now many people talk about Chinese shipbuilding, and how did we go there, right. Right now, based on USTR data, Chinese has been creating, making more than 1,000 ships annually, and in the meantime for the U.S. only 5, perhaps less than 5 commercial ships. So a huge gap there.

And now we are witnessing robotic AI going to that way. So China already occupies the industrial base for more than like 50 percent in the world, talking about industrial robots. So if the U.S. does not act fast with their allies to ensure the strength in the industrial productivity and production, I am so afraid that we are losing this in the future.

COMMISSIONER PRICE: Thank you. Dr. Endy, any last thoughts on

recommendations?

DR. ENDY: Let me give you a softball back, Chair Price. Bio.gov, a simple website that represents what the United States of America is about and our aspirations regarding the future of biotechnology. We used to have something like this for AI.gov, but there has been a little bit of a hiccup in terms of where that URL redirects. So this has to be done in a way that sustains across administrative transitions.

But something like that, something that says this is what we are about, that lets everybody, from entrepreneurs to allies and partners, you name it, like where is our coordination solution for our dream about a flourish and American biotic future. Thank you.

COMMISSIONER PRICE: Thank you.

VICE CHAIR SCHRIVER: Thank you. We are right at time. I appreciate all the witnesses for your contributions. We occasionally ask questions for the record after. You all are volunteers, and you have already given us so much. But if there were follow-on questions we hope you will have an opportunity to address them and get back to us.

We are now going to take a short break, 9 1/2 minutes, not 10, and reconvene on time. Thanks.

[Recess.]

PANEL II INTRODUCTION BY COMMISSIONER MICHAEL KUIKEN

COMMISSIONER KUIKEN: Thank you very much for being here today, folks. This is our next panel. Our next panel will project the technology targets in China, China's future economic and industrial strategies, examine its capacity to achieve those targets, and evaluate the effectiveness of U.S. and other countries' technology restrictions on China.

We will start with Mr. Tim Khang, the Director of Global Intelligence at Strider Technologies. Thank you for being here, Mr. Khang.

Then we will go to Ms. Emily de La Bruyère -- hopefully I pronounced that right, Emily. I am sorry if I did not. I apologize. Ms. de La Bruyère is the Co-Founder of Horizon Advisory and a Senior Fellow at the Foundation for the Defense of Democracies.

And then we will hear from Hanna Dohmen, Research Analyst at Georgetown University's Center for Security and Emerging Technologies.

And finally we will hear from Mr. David Lin, Senior Director for Future Technology Platforms at the Special Competitive Studies Project.

Thank you to all of you for your wonderful testimony or your submitted statements. The Commission is looking forward to hearing your remarks. And we will go through seven minutes for your round, and then we will go through a series of questions, and then we will go from there.

Thank you very much to everyone, and Mr. Khang, we will start with you.

OPENING STATEMENT OF TIM KHANG, DIRECTOR OF GLOBAL INTELLIGENCE, STRIDER TECHNOLOGIES

MR. KHANG: Thank you, Commissioner. Co-Chairs Schriver and Kuiken, Commissioners and staff, thank you very much for the opportunity to participate in today's hearing.

My testimony will focus on China's talent acquisition mechanisms because it really, truly lies at Xi Jinping's stated strategy for global technological dominance. I would also like to touch on how China's talent strategies have evolved over the years and powered the success of Made in China 2025.

By way of a quick introduction, I work for Strider Technologies. Strider collects publicly available data, primarily from sources in adversarial nations, and transforms them into actionable intelligence.

Thirty years ago, China's economy and technology was so far behind world leaders that its top minds and scientists had really nowhere to go but abroad to participate in cutting-edge research. It was a gap that was recognized by the PRC government, and they began an aggressive and systematic campaign to absorb talent and technologies from around the world.

The challenge for the United States and its allies is now there is a flywheel effect of talent spotting and absorption that shows no sign of slowing even though China's domestic ecosystem for innovation is more powerful than ever before.

This is what I came here to say today. I just got a couple of points. There has been no coordinated effort from the United States or its allies to counter China's talent acquisition efforts. We have failed to stop the PRC talent absorption machine.

Second, unlike China, the United States has no centralized strategy for attracting and keeping the best talent in this country. When it comes to the competition for talent, the United States is like a naturally gifted athlete who doesn't practice, doesn't have a coach, and relies on improvisation and intuition to win games. China, on the other hand, might be compared to a less-talented athlete, but is bigger than us, has a coaching staff, and works out every day. If we are to win this competition, we need a coaching staff, we need a strategy, and we need to practice.

For the rest of my testimony I would like to tell the story of how China got to where it is today, give some examples of their tactics and their procedures.

So how did we get here? Let's start with Xi Jinping. The order comes down from the very top. Over and over, in his speeches and directives, Xi commands and calls on the PRC and the CCP to win the competition for global talent. This push for talent acquisition is enshrined in the all-important CCP document known as "Xi Jinping Thought." The word for "talent" (rencai) appears no less than 34 times in this document.

When an order like this comes down, there is this entire ecosystem of organizations in the CCP, the government, academia, and industry that mobilizes themselves to execute Xi Jinping's plans, and this is how it worked for Made in China 2025.

In 2015, the National Advisory Committee implementing the MIC 2025 policy published a 190-page document called the "Technology Roadmap for Made in China 2025." It specified almost 2,000 technologies targeted for systematic acquisition. When Strider took these technology terms and matched them up with the expertise of the people who work at the top 1,000 companies around the world, even with the most conservative matching algorithms, we got more than 1.1 million people matching for potential targets for recruitment.

This is how it works on the ground. If you have expertise that matches up and aligns with

the technologies that are specified in MIC 2025, your chances of being recruited or approached by a PRC recruiter increases significantly. We see this every day at Strider, and I saw it firsthand working in the HR industry throughout the 2010s in China myself.

China's central government reported that its talent programs have recruited at least 60,000 talents from overseas, and that is a figure from 2016. They stopped publishing this data -- smart on them -- but Strider has been tracking over 400 talent programs, and we know that even with the most conservative estimates, this number has got to be well over 100,000 people by now. And even just the Thousand Talent Program, which aimed to attract 1,000 talents, that number is over 10,000, so they really blew past their goals.

This type of centralization coordination stretches through private HR companies in China and also to nonprofit organizations based right here in the United States. These "private" HR companies recruit talent on behalf of the CCP with the stated purpose of, quote, "strengthening the country through talent introduction."

Now, using these private companies has a lot of benefits. It gives a sheen of legitimacy to the recruitment efforts and plausible deniability for the CCP. And some of these companies have raised hundreds of millions of dollars in our stock markets, in the U.S. stock exchanges. I mean, talk about adding insult to injury here.

And it is not just the domestic Chinese companies that the CCP controls. There is a 501(c) nonprofit ecosystem in the U.S. Let me give you one example. This one is based in Atlanta, Georgia, whose main source of income is the PRC government. Its leader was honored by none other than Xi Jinping in 2014, for, quote, "using the Georgia Institute of Technology as a platform to train more than 110 graduate students and visiting scholars for China."

During my time at Strider I have seen hundreds of examples of this, and perhaps the most important macro-level shift in China's tech transfer strategies is the rising number of research collaborations with risky entities. Of particular concern is the increase in the number of collaborations with organizations affiliated with the PRC military. Since 2017, more than 250 organizations in the U.S. have collaborated with at least 50 PRC military-affiliated research institutes on STEM-related topics, on thousands of publications. Our higher education system is the soft underbelly of our innovation environment. The CCP knows it, and they are taking advantage of it.

For decades, the PRC government has leveraged both returning talent and homegrown innovation to advance towards technological self-sufficiency, and by adapting to new challenges with innovative strategies the PRC continues to find ways through our fences. And if we do not act, and act soon, this will simply continue. And we cannot expect to win the competition with China by relying on our natural gifts and our good looks.

In my written testimony I offer some more detailed policy recommendations. I look forward to delving in a bit further during the Q&A portion. Thank you very much.

PREPARED STATEMENT OF TIM KHANG, DIRECTOR OF GLOBAL INTELLIGENCE, STRIDER TECHNOLOGIES

Testimony before the U.S.-China Economic and Security Review Commission
Hearing on "Made in China 2025 – Who is Winning?"

Tim Khang
Director, Global Intelligence
Strider Technologies[1]

February 6, 2025

Co-chairs Schriver and Kuiken, commissioners and staff, thank you very much for the opportunity to participate in today's hearing.

The People's Republic of China (PRC) has employed a whole-of-government-and-society approach to implement its Made in China 2025 initiative. Through direct subsidies, cheap credit, forced technology transfer, talent acquisition, and outright theft, many sectors have made undeniable gains in the past 10 years. The PRC is now the world's leading exporter of automobiles and drones, boasts the largest network of high-speed railways, and dominates the shipbuilding and renewable energy sectors. But China still faces challenges in critical sectors such as semiconductors and agriculture, and international pushback against its unfair practices is coalescing.[2] [3] [4]

This testimony will focus on the PRC's talent acquisition mechanisms, which have not only powered the successes of Made in China 2025 but also lie at the heart of Xi Jinping's stated strategy for global technological dominance in the future.

The PRC government has taken a coordinated and systematic approach to talent acquisition since at least the 1990s. Since the promulgation of MIC2025, the PRC has greatly expanded its foreign talent acquisition apparatus, deployed new tactics in the face of external shocks, and appears to have succeeded in creating an indigenous ecosystem of innovation in some sectors that rivals that of the United States. The PRC has succeeded in creating a

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[1] Strider is a strategic intelligence company empowering organizations to secure and advance their technology and innovation. By leveraging cutting-edge AI technology alongside proprietary methodologies, Strider transforms publicly available data into actionable intelligence. This intelligence enables organizations to proactively address and respond to risks associated with state-sponsored intellectual property theft, targeted talent acquisition, and supply chain vulnerabilities.

[2] https://automobility.io/2024/09/the-path-to-globalization-of-chinas-automotive-industry-2024/

[3] "An Initiative So Feared that China Has Stopped Saying its Name," The Economist, 2025. https://www.economist.com/china/2025/01/16/an-initiative-so-feared-that-china-has-stopped-saying-its-name

[4] "The World China Made," Office of Senator Marco Rubio, 2024. https://www.americanrhetoric.com/speeches/PDFFiles/Marco-Rubio-The-World-China-Made.pdf

flywheel effect of talent spotting and absorption which shows no sign of slowing even though it now possesses more capacity for domestic innovation than ever before.

The Order Comes Down from the Very Top

The speeches given by Xi at the 18th, 19th, and 20th National Congress of the Chinese Communist Party (CCP) prominently features the global competition for talent. In the body of enshrined text known as "Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era," the word "talent" appears 34 times. [5] Xi calls on the CCP to "more clearly emphasize that…talent is the primary resource to support development," and to "accelerate the construction of the world's important talent center…and strive to form a comparative advantage of international competition for talents."[6]

National priorities laid out in "Xi Jinping Thought" are interpreted and executed by subordinate Communist Party, governmental, industrial, and academic organizations. These organizations provide additional input to national talent acquisition plans, devise tactics and procedures for talent attraction, and allocate resources to implement those plans.

PRC Talent Policy Mechanisms Were Ready for MIC2025

The National Manufacturing Power Construction Strategic Advisory Committee, the decision-making body responsible for implementing MIC2025, specified in great detail the "key technology areas" to be targeted in MIC2025 in a 190-page document called the "Technology Roadmap for Key Areas of Made in China 2025."[7] The document's purpose was to "guide market and social resources" and to "serve as a reference" for all levels of government and industry to focus their efforts on the absorption and development of specified targeted technologies. The Technology Roadmap details almost 1,800 technologies in ten broad industry sectors targeted for systematic acquisition through large-scale technology and talent transfer.

Even with the most conservative matching parameters, Strider's analysis of open-source data shows that these technologies matched with the technical expertise of at least 1.1 million people across the top 1000 non-PRC private enterprises around the world.[8] My own experience in China's HR industry in the 2010s, coupled with countless examples of outreach to talent at Strider's client organizations have taught me that high visibility of expertise that align with the MIC2025 Technology Roadmap greatly increases an individual's chances of being approached by PRC recruiters. The clarity with which MIC2025 defines the PRC's targeted technologies allowed government authorities and industry players to focus their recruitment efforts on talent that fit the descriptions laid out in the Technology Roadmap.

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[5] https://www.airuniversity.af.edu/Portals/10/CASI/documents/Translations/2023-10-30%20ITOW%20Xi%20Jinping%20Thought%20on%20Socialism%20with%20Chinese%20Characteristics%20for%20a%20New%20Era.pdf

[6] https://www.reuters.com/world/china/key-xi-quotes-chinas-20th-communist-party-congress-2022-10-16/

[7] Technology Roadmap for Key Areas of Made in China 2025, National Manufacturing Power Construction Strategic Advisory Committee, 2015. https://www.cae.cn/cae/html/files/2015-10/29/20151029105822561730637.pdf

[8] The criteria for determining the "top 1000" private enterprises included annual revenue, market capitalization, employee count, and other factors.

By the time MIC2025 launched in 2015, major talent acquisition efforts which began in the 1990s and 2000s had already established the incentives and infrastructure needed to make MIC2025 a success. For example, the Ministry of Human Resources and Social Security (MOHRSS) reported that the Thousand Talent Program alone had attracted 5,208 overseas talents by 2015.[9] MOHRSS stopped the publication of aggregate talent program statistics around 2017, but the most recent figures show that between 2008 and 2016, various national and local talent programs had recruited at least 60,000 talents from overseas.[10] Following the promulgation of MIC2025, the PRC central government called on organizations and individuals to align their talent recruitment and technology development priorities to implement the goals laid out in MIC2025.[11]

The CCP Controls PRC Talent Policy Development and Evaluation

The Chinese Communist Party does not rely on markets or organic forces alone to achieve its goal of attaining the status of a "talent superpower." Strategy conception and evaluation is centralized, which allows the PRC to mobilize all government and societal resources to make necessary adjustments and continuously improve incentives.

The CCP has designated an entity called the Chinese Academy of Personnel Sciences (CAPS) as the national center for the study, development, and evaluation of talent policies.[12] As the so-called "Talent Theory Research Base" of the CCP, CAPS has contributed to the development of national programs such as the Thousand Talents Program, published studies on the efficacy of various talent acquisition strategies, and formulated countermeasures to U.S. legislation such as the CHIPS Act.[13] Here are a few illustrative examples of the research conducted by CAPS:

- "Overseas Talents' Entrepreneurial Competency and Personality Research"[14]

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[9] "Thousand Talents Program Introduced 5,208 High-Level Overseas Talents." Overseas Chinese Affairs Office, 2016. https://www.gqb.gov.cn/news/2016/0107/37723.shtml

[10] Alex Joske, *Hunting the Phoenix*, Australian Strategic Policy Institute, 2020. https://www.aspi.org.au/report/hunting-phoenix

[11] Li Jinhua, "Building a Strong Manufacturing Nation Requires a Complex Path of Action" (建设制造强国需要复合行动路径), 2017. http://paper.people.com.cn/rmrbhwb/html/2017-05/30/content_1778360.htm

[12] https://baike.baidu.com/item/%E4%B8%AD%E5%9B%BD%E4%BA%BA%E4%BA%8B%E7%A7%91%E5%AD%A6%E7%A0%94%E7%A9%B6%E9%99%A2/10655430

[13] Li Yuhan, Long Yunfeng, Chen Jie, "Influences of US "Chips Act" on Talent Mobility in Chip Industry and the Countermeasures" (美国"芯片法案"对芯片领域人才流动的影响与应对), 2023. https://qikan.cqvip.com/Qikan/Article/Detail?id=7110947606

[14] https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=6c0c9f2c85d5d06039ced01626bcfa61fbc83ade

- "Third Party Assessment on Chinese Returned Oversea Talent Introduction Projects: A Research based on Pearl River Talent Project"[15]
- "Influences of US "Chips Act" on Talent Mobility in the Chip Industry and the Countermeasures"
- "Research on the Restrictive Factors and Countermeasures of Overseas Talent Introduction by Headhunting Agencies — Taking Shanghai as an Example"[16]

Over the past two decades, CAPS has been studying the art and science of talent absorption and cultivation. It has helped implement new ideas, collected data, tested the efficacy of policies, and driven the constant evolution of tactics, techniques, and procedures (TTPs) of talent attraction. The findings from research conducted by CAPS are channeled to government policymakers, Communist Party officials, and relevant industry partners to create new talent policies and make necessary adjustments to old ones. CAPS research has been influential in several notable TTP evolutions:

- From 2012 to 2017, preferential policies for visa and residence permit processing was gradually expanded to include local and ministerial-level talent programs, resulting in a constellation of programs which offered lower barriers for relocation to various regions of the PRC.[17]
- Starting in 2015, the incubation system for young overseas talent relocating to the PRC was improved, resulting in the construction of more than 300 "entrepreneurial parks" with subsidized housing and other benefits that created a more ideal environment for innovation.[18]
- In 2016, a series of public policy discussions led by the head of CAPS transformed talent spotting techniques to leverage Big Data and cloud computing technologies.[19]

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[15] Information on this research publication has been taken down from the open source and is only available in Strider's internal data holdings.
[16] https://qikan.cqvip.com/Qikan/Article/Detail?id=7111085374
[17] "Deepening the Reform of the Talent Development System and Mechanism, Forming a National Talent Strategy with Clear Logic, Clear Levels, Complete System and Mutual Support, So that the Vitality of Talents Will Surge, Which Will Surely Promote China's " Position " in the Global Economic Development and Scientific and Technological Innovation Race" (深化人才发展体制机制改革，形成逻辑清晰、层次分明、体系完整、互为支撑的国家人才战略有机体系，让人才活力澎湃奔涌，必将推动我国在全球经济发展和科技创新赛跑中"身位"不断向前), 2017. The primary source for this research publication has been taken down from the open source and is only available in Strider's internal data holdings.
[18] Ibid.
[19] "Wang Tongxun: Talent Introduction: How to Make Good Use of Big Data as a Powerful Tool" (王通讯：人才引进，怎么用好大数据这个利器), Center for China and Globalization, 2016. http://www.ccg.org.cn/archives/29380

- In 2019, a policy adjustment enabled selectees of national-level talent programs (such as the Thousand Talent Program) to obtain permanent residence for family members. The policy also simplified entry and exit procedures for talent program selectees, reducing the burden of relocation to the PRC.[20]

The current maturity of the PRC's talent acquisition machine is the result of decades of organized effort to create the most effective system to achieve the goal of gaining a "comparative advantage of international competition for talents."

It is important to note that CAPS maintains an intimate connection to the United Front Work System ("United Front")[21], which coordinates the CCP's policymaking and international operations to identify and attract talent from foreign countries. Thought leaders on the topic of talent acquisition simultaneously hold positions in institutions like CAPS and the United Front Work System; this deliberate overlap allows the United Front to play a central role in the PRC's competition for global talent.

The CCP Leverages Private Talent Recruitment Companies

In 2021, the CCP created the Human Resources Service Industry Committee of the All-China Federation of Industry and Commerce (ACFIC), a "national umbrella organization of private entrepreneurs" directly-run by the United Front Work Department.[22] [23] ACFIC's HR Service Industry Committee is composed of around 150 leaders from both public organizations and private companies in the PRC's HR service industry, and is "guided by Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era" with the stated purpose of "strengthening the country through talent [introduction]."[24] The Committee "actively implements the spirit of the Central Talent Work Conference," a seminal meeting of top CCP leaders where Xi Jinping stressed the importance of "building a strong country with talents" for the "basic realization of socialist modernization by 2035."[25] [26]

The ACFIC HR Committee is an example of how the United Front coordinates the actions of private companies to advance the CCP's goals. There is nothing inherently nefarious about companies competing for the best talent, so this gives a sheen of legitimacy to the efforts of PRC talent recruitment firms and plausible deniability for the CCP.

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[20] "Zhongguancun Releases 20 New Policies for International Talents," Beijing Daily, 2019. http://www.yxjcrc.com/m/view.php?aid=1092

[21] The United Front Work *System* is a blend of influence activities and intelligence operations that the CCP uses to shape its political environment and gain access to advanced foreign technology. The United Front Work *Department* is the lead working organ of the CCP's Central Committee which coordinates the work of the United Front Work System both inside and outside of the PRC.

[22] Sebastian Heilmann, *China's Political System*, 2017, p270.

[23] Alex Joske, *The Party Speaks for You*, 2020. https://www.aspi.org.au/report/party-speaks-you

[24] Official webpage of the ACFIC HR Service Industry Committee. https://www.acfic.org.cn/bhjj/zzjg/hywyh/2021_rlzyfwywyh/

[25] Ibid.

[26] "Xi Jinping attended the Central Talent Work Conference and Delivered an Important Speech," Xinhua News Agency, 2021. https://www.gov.cn/xinwen/2021-09/28/content_5639868.htm

On the ground, this means that U.S. enterprises feel the brunt of this effort manifested in the constant onslaught of recruitment efforts targeting their employees. During my time at Strider, I have seen hundreds of examples of outreach from recruiters employed by many of the member companies of the ACFIC HR Committee. Here are a few prominent examples:

- BOSS Zhipin (also known as BOSS App or BOSS Direct Hire): claims to be the largest hiring and recruitment platform in China by count of monthly active users. In June 2021, BOSS Zhipin went public on the NASDAQ stock exchange, raising USD $912 million. [27] BOSS Zhipin's CEO is the chairman of the ACFIC HR Committee.
- Liepin (also known as Wise Talent Information Technology): bills itself as "the largest and most professional high-end talent community-based recruitment site."[28] Liepin's CEO is a member of the ACFIC HR Committee.
- Zhaopin.com: known as "one of the largest online recruitment platforms in China." Listed on the New York Stock Exchange in 2014, raising over USD $170 million in its IPO.[29] Zhaopin's chairman and president is a member of the ACFIC HR Committee.

The United Front Has Established Talent and Tech Absorption Infrastructure Abroad

In addition to leveraging domestic assets, the PRC government has enacted a series of programs which use organizations in the United States, Europe, and other offshore geographies to gather intelligence on new technologies, recruit talent, and leverage foreign IP to advance the PRC's S&T goals. I would like to highlight two types of organizations currently active in the United States that demonstrate the methods and effectiveness of their operations.

Overseas Innovation and Entrepreneurial Bases[30]

The HOME program, short for "Help Our Motherland through Elite Intellectual Resources from Overseas Program," is a talent and technology transfer program established under the leadership of the China Association for Science and Technology (CAST). CAST is an official component of the Chinese People's Political Consultative Conference (CPPCC), part of the United Front Work System.[31] The program's aim is to build platforms to recruit talent to "serve the motherland" while they remain working overseas.

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[27] Beau Parrish, "BOSS Zhipin (BOSS 直聘): The Most Active Job Portal in China," 2024. https://teamedupchina.com/boss-zhipin/

[28] https://www.crunchbase.com/organization/liepin-com

[29] Beau Parrish, "Zhilian Zhaopin (智联招聘): An Overview of the Cinese Job Platform," 2024. https://teamedupchina.com/zhilian-zhaopin/

[30] Willian Hannas and Didi Kirsten Tatlow, *China's Quest for Foreign Technology*, Routledge, 2021.

[31] Alex Joske, *Hunting the Phoenix*, Australian Strategic Policy Institute, 2020.

CAST-USA is one of the U.S.-based S&T organizations listed as an overseas S&T group liaising with the HOME Program, and is registered as a tax-exempt 501(c)(3) non-profit organization with the IRS. CAST-USA is organized into at least 16 chapters around the country and claims more than 10,000 members, "working in universities, industries, government agencies and other sectors, many in the world's top 500 multinational corporations."[32] [33] The HOME Program, along with overseas S&T groups like CAST-USA, employs various forms of activities, such as international academic exchanges, research cooperation, technical consulting, and technology introduction to contribute to the PRC's S&T advancement.[34] The HOME program is designed to direct the flow of foreign technology to the dozens of HOME program centers located across the PRC, and to direct the flow of people to programs such as the Thousand Talents Program.

Since 2014, CAST began the establishment of so-called Overseas Innovation and Entrepreneurial Bases. Located near innovation hubs such as Silicon Valley and Boston, these Bases better enable recruited talents to feed intellectual property back to the PRC for commercialization without physically relocating to the PRC. For example, overseas talents who take part in the HOME program can monetize research conducted in their host country via a stake in a commercial enterprise in the PRC by "technology for equity" exchange.[35] This model allows a more flexible connection of overseas innovation resources with incubation teams in China that commercialize their innovative ideas.

As with other national-level talent programs, PRC authorities stopped publicizing aggregate statistics about the HOME program around 2017. However, according to the latest reporting by CAST, the HOME program has received no less than 8,651 overseas science and technology personnel at HOME Program work bases in China, and held 1,012 "recruitment docking activities"[36] which yielded 1,099 signed cooperation agreements and negotiations on 5,928 start-up projects, of which 1,267 have relocated to China. The HOME program has also resulted in at least 145 people being selected for the Thousand Talents Program.[37]

Although the PRC no longer publishes national-level data on the HOME program, there is ample evidence that the program continues to direct talent and technology to the PRC. For example, in January 2025, the Guangdong Provincial branch of CAST publicized the results of its 2024 HOME program. In 2024, the HOME program centers

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[32] Invitation Letter for Yale Summit 2018 on Science and Technology Innovation and Economic Leadership and The 26th Annual Conference of Chinese Association for Science and Technology, USA http://docs.wixstatic.com/ugd/ad4f2f_6bc56210a1254944a88810695d15d5f5.pdf

[33] About CAST-USA. https://GNY, castgny.org/en/index.php/about-us-3/

[34] Official webpage of CAST. http://hzb.cast.org.cn/col/col264/index.html

[35] "Zhi Gong Party Central Committee: Proposal on building a new model of offshore innovation and entrepreneurship to attract overseas talents to serve the country"(致公党中央：关于构建离岸创新创业新模式吸引海外人才为国服务的提案) http://tyzx.people.cn/n1/2018/0227/c417761-29837415.html

[36] "Docking" is a PRC term of art that refers to forums connecting overseas entrepreneurial talents possessing technology, intellectual property, and know-how with PRC investors, enterprises, industrial parks, and/or government entities in order to relocate innovative projects to the PRC.

[37] http://www.xunmv.com/news/show-4311.html

managed by Guangdong CAST "carried out 717 technology matchmaking activities, introduced 569 projects, introduced 200 high-quality teams from overseas, introduced 762 outstanding talents…and carried out 117 overseas intelligence activities."[38] Other provincial branches of CAST such as Gansu and Sichuan have already announced plans and application procedures for the 2025 HOME program.[39] [40]

Overseas Talent Workstations

Overseas Talent Workstations are paid by PRC authorities to facilitate the identification and recruitment of high-level talents abroad for introduction into the PRC. Besides a base payment, these Workstations qualify for performance-based bonuses.[41] The China-US Technology Innovation Center (CUTIC) is a 501(c)(3) non-profit professional organization founded in 2015 and headquartered in the suburbs of Atlanta, Georgia.[42] CUTIC serves as an official North America Overseas Talent Workstation for around a dozen PRC municipal governments. The organization offers a range of services such as exchanging information on talent and technology projects, connecting U.S. tech companies with advanced manufacturers in the PRC, and connecting would-be entrepreneurs in the United States with PRC government-backed venture capital funds. CUTIC organizes recruitment events and implements PRC talent recruitment programs, representing an increased risk of talent recruitment, technology transfer, and intellectual property theft. The organization has branch offices in the PRC provinces of Jiangsu and Zhejiang, the Chongqing Municipality, as well as Florida, California, and Oregon.[43]

CUTIC's leadership consists of individuals who have been recruiting talent from the U.S. since at least 2005. The current director runs a for-profit "management consulting" business from the same address as the non-profit CUTIC, that is advertised as a consulting firm that cooperates with local PRC governments and introducing U.S. high-tech talents to the PRC. Another board member has organized several events which hosted PRC government officials accused of talent theft and espionage, such as the U.S. Representative of the Zhongguancun High-Tech Park and officials from the now-defunct PRC Consulate General in Houston. Finally, CUTIC has an advisory committee member who is a Thousand Talents Program selectee and a Foreign Academician of the Chinese Academy of Sciences – this individual was honored with an International Science and Technology Cooperation Award in 2014 by top PRC leaders (including Xi Jinping and Li Keqiang) for "using the Georgia Institute of Technology in the United States as a platform to train more than 110 graduate students and visiting scholars for China."[44]

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[38] http://www.jiangmen.gov.cn/home/bmdt/content/post_3229929.html
[39] "Notice on the Application for the 2025 Gansu HOME program" https://kjc.gipc.edu.cn/info/1045/2227.htm
[40] "2023-2025 Sichuan Association for Science and Technology HOME Program Special Expert Invitation" http://www.funresearch.cn/experted/browse/MDc0YjE2YTAtNjM4ZS00YzU2LWI4OWItYjIzNDdjYWM3MzMx
[41] Notice on Issuing the "Management Measures for Overseas Talent Workstation in Nantong, China (Trial)," 2017. Primary source document for this information has been taken down from the open source and is only available in Strider's internal data holdings.
[42] https://www.linkedin.com/company/cutic
[43] Official webpage of CUTIC. Primary source documents for this information have been taken down from the open source and is only available in Strider's internal data holdings.
[44] Ibid.

Strider's internal data shows that CUTIC has stepped up its talent recruitment efforts in recent years, expanding its operations to several U.S. states and targeting engineers and scientists of U.S. enterprises and universities with access to sensitive technologies. CUTIC regularly solicits responses from these employees via email and social media campaigns, inviting them to join their recruitment events, mailing lists, and WeChat group.

CUTIC is just one example of hundreds of Overseas Talent Workstations operating outside of the PRC. Like Overseas Innovation and Entrepreneurial Bases, these Workstations are under the umbrella of the United Front Work System and take advantage of the laws and infrastructure of the host country to carry out the talent and technology agenda of the CCP.

PRC Talent Acquisition Strategies Adapt to External Forces

Several major events outside the control of the PRC government have changed the way it conducts talent and technology acquisition operations. When the COVID-19 pandemic shut down international travel, foreign talent recruitment activities went virtual, and talent program selectees were offered greater flexibility to remain employed abroad to "serve the motherland through various methods" as laid out by an earlier policy.[45] [46] When LinkedIn shut down its services in the PRC in August of 2023, Strider's Global Intelligence team noticed a spike in email campaigns from PRC recruitment firms. But perhaps the most important macro-level shift is the rising number of academic collaborations between PRC research institutions and their overseas counterparts. As governments and enterprises around the world placed greater scrutiny on the PRC's talent and technology transfer activities, the PRC government has increasingly called on local authorities and research institutes to "expand international academic exchanges…and scientific research cooperation."[47] Of particular concern is the increase in the number of collaborations with organizations affiliated with the PRC military. Strider's analysis of research publication data has revealed the following:[48]

- Since 2017, more than 250 U.S. organizations have collaborated with at least 50 PRC military-affiliated research institutes on STEM-related topics on thousands of publications. This amounts to more than 20,000 instances[49] of collaboration between U.S. researchers and PRC military R&D organizations.[50]

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[45] "Job Recruitment in China Goes Online Amid COVID-19 Epidemic," PRC State Council, 2020. https://english.www.gov.cn/news/videos/202003/15/content_WS5e6dcec9c6d0c201c2cbe5bc.html

[46] "Some Opinions on Encouraging Overseas Scholars to Serve Their Country" (关于鼓励海外留学人员以多种形式为国服务的若干意见), 2001, Preamble. http://www.moe.gov.cn/jyb_xxgk/gk_gbgg/moe_0/moe_7/moe_16/tnull_167.html

[47] "China Calls for Overseas Education Ventures in Push for Tech Advancement," South China Morning Post, 2025. https://www.scmp.com/economy/policy/article/3295487/china-calls-overseas-education-ventures-push-tech-advancement

[48] These figures are based on Strider's analysis of open-source data.

[49] One publication may contain multiple "instances" of collaboration depending on the number of co-authors.

[50] "PRC military R&D organizations" include Seven Sons universities, research laboratories and universities run by the PLA, military training academies, and PRC defense conglomerates.

- Strider identified more than 3,000 instances of U.S. researchers publishing STEM research with a concurrent affiliation to a PRC military-affiliated research institute since 2017.
- Strider identified hundreds of publications featuring U.S. researchers that received funding from PRC military and other strategic PRC funding programs. Strider identified thousands of instances of the U.S. government funding research that features an author from a high-risk PRC military research institute.

The PRC Has Succeeded in Creating a More Independent Indigenous Innovation Ecosystem

For decades, the PRC government has strategically cultivated a culture of innovation through a robust framework of financial, political, and social incentives. This approach has fostered a new generation of domestic pioneers while celebrating figures such as Pan Jianwei, the scientist trained in Austria and Germany known as China's "father of quantum computing," and Huang Boyun, one of the earliest overseas returnees who brought back critical aviation technology expertise from the United States. By leveraging both returning talent and homegrown innovation, China has steadily advanced toward technological self-sufficiency.[51] [52]

Thirty years ago, the PRC's lack of economic prowess and innovation capacity meant that its only path to advancement was learning from more developed nations. However, after three decades of aggressive talent and technology acquisition, the PRC has achieved near parity in sectors such as quantum computing and AI and has even surpassed leading economies in areas like electric vehicles, high-speed rail, and renewable energy. While China still lags in critical industries like semiconductors and has yet to meet its MIC2025 goals in agriculture, its domestic innovation ecosystem is now robust enough to foster groundbreaking companies. A prime example is DeepSeek, whose founder, Liang Wenfeng, has claimed that the company's core team is composed entirely of talent from domestic universities, with no reliance on overseas returnees.[53] This shift underscores China's broader strategic move toward technological self-reliance, reducing dependence on foreign expertise while leveraging homegrown innovation.

Using a sprawling cultural and organizational infrastructure built over decades, and by adapting to new challenges with innovative strategies, the PRC continues to find ways through our fences. To maintain its competitive edge and prevent strategic dependencies, the United States must invest in domestic research and development, strengthen information sharing with allies, and adopt proactive measures to counter the PRC's evolving talent and technology acquisition strategies.

Policy recommendations

To effectively counter the PRC's talent and technology acquisition policies while upholding the values of the free world, I would like to close my testimony with some policy recommendations:

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[51] "Quantum Dragon Report," Strider Technologies. https://www.striderintel.com/resources/quantum-dragon-report/

[52] "Huang Boyun, Refused an Offer 80 Times the Salary from the US and Broke the Foreign Technology Blockade after returning to China," https://m.163.com/dy/article/HAFPS25A0543L395.html

[53] https://www.pressreader.com/china/south-china-morning-post-6150/20250128/281913073790983?srsltid=AfmBOoo8eWdbPoyBKQLHYDhTWZ3SfRLvE91Q7rF_KAcFTrmr48tXlMif

- **Mandate Transparency and Disclosure for Research Institutions**
  Congress should require all national laboratories, research institutes, and universities to disclose collaborations with PRC military-affiliated entities, particularly in research involving dual-use technologies. These requirements should extend beyond the provisions outlined in National Security Presidential Memorandum 33, ensuring comprehensive research security measures across public U.S. institutions.
- **Restrict United Front-Linked Companies from Accessing U.S. Capital Markets**
  Congress should enact legislation preventing PRC companies from raising capital through U.S. stock markets if their leadership holds positions in CCP United Front organizations. These committees actively direct companies to recruit U.S. talent and undermine U.S. national security interests. Strengthening investment restrictions would ensure that American financial markets do not inadvertently fund entities working against U.S. strategic objectives.
- **Enhance Transparency in Corporate Procurement and Research**
  Publicly traded U.S. companies should be mandated to disclose procurement and research relationships with organizations which supply and collaborate with the People's Liberation Army or other PRC government entities. Promoting such transparency would reduce dependencies on entities tied to militaries and governments of adversarial nations.
- **Review Certain 501(c)(3) Organizations**
  The U.S. government should conduct a review of nonprofit organizations (i.e., 501(c)(3)) whose primary funding comes from adversarial governments, especially if their purpose aligns with advancing the technological capabilities of such nations. This review would help ensure these organizations operate in alignment with U.S. national security interests.
- **Establish a National Talent Research Center**
  Congress should pass legislation to create and fund a national-level research center dedicated to studying global talent dynamics. This center would monitor talent policies of adversarial nations and develop a cohesive national strategy to strengthen the U.S. position in the global competition for talent.
- **Reform H-1B and Permanent Residency Policies**
  Congress should overhaul H-1B immigration policies by increasing the annual cap and transitioning from a lottery-based system to a merit-based one. Additionally, eligibility criteria for EB-1, EB-2, and EB-3 pathways to permanent residency should be streamlined to allow workers in STEM fields to qualify more easily.

OPENING STATEMENT OF EMILY DE LA BRUYÈRE, CO-FOUNDER, HORIZON ADVISORY, AND SENIOR FELLOW, FOUNDATION FOR DEFENSE OF DEMOCRACIES

COMMISSIONER KUIKEN: Go ahead. We will just go straight down the table.

MS. DE LA BRUYÈRE: Perfect. Hearing Co-Chairs, distinguished Commissioners and staff of the USCC, and, of course, fellow panelists, it is an honor to participate in today's hearing. Thank you.

China uses its industrial capacity to project power. Beijing sees industrial strength not only as a means to enhance the nation's economic prowess, military capabilities, and social system. Industrial strength also secures the asymmetric dependence of the rest of the world. Beijing uses that dependence for strategic ends, in order to tie foreign incentives to China's own, and ultimately to shape foreign markets, politics, information, technology, and, in a self-reinforcing fashion, industry itself.

In other words, Beijing is using industry to overtake and to overpower the United States. This is the ambition of Made in China 2025, and in China's larger ecosystem of industrial policies and investments.

The stakes for the U.S. are enormous. The Made in China 2025 plan is the first of three 10-year programs that are intended to build China into the world's dominant industrial power, and therefore the world's dominant power. Should the CCP realize its ambitions, the U.S. industrial and defense industrial bases will become entirely reliant on China.

That, in turn, will mean that China can shape, determine, influence the prosperity and security that depend on those bases. Beijing will be able to decide what companies win and lose, have access, for instance, to critical technology, inputs, markets. And, therefore, Beijing will be able to shape the American political and social system that depends on, and is influenced by markets. Moreover, in a modern technological environment, China's control over American industry will give it control over American information.

Ten years ago, when Beijing issued Made in China 2025, to paint this future was to describe an abstract, almost impossible threat. Today, there is nothing abstract about it. The priorities of Made in China 2025 include, for instance, telecommunications equipment and network security. Today, Beijing has infiltrated virtually the entire U.S. telecoms network.

New energy sectors, like solar and batteries, as well as the critical materials on which they depend also figure in the priorities of Made in China 2025. Today, China controls about 90 percent of the global solar value chain and a similar share in batteries, including 80 percent of graphite supply.

Made in China 2025 also prioritizes advanced semiconductor packaging. China is the dominant global player in that field too, with more than 50 percent of global market share. That means that even the quote/unquote "crown jewels" of the U.S. semiconductor ecosystem and global semiconductor ecosystem are shipping their products to China for packaging. It also gives China a means to evade U.S. tech restrictions.

These cases reflect Made in China 2025 working and hurting the United States. They give China, respectively, control over American information, energy, technology, and across-the-board markets. They also show the U.S. failure to respond, even in the fields that have been most prioritized in American policy. In telecommunications, a battery of U.S. company-level restrictions on Chinese state champions have not stopped China from infiltrating our networks, nor have they stopped U.S. companies from depending on, selling to, and lobbying on behalf of

Chinese players, known bad actors, and unknown ones, Huaweis and hidden Huaweis.

In semiconductors, new energy, and critical materials, the U.S. has issued unprecedented government support to try to support domestic industry. That has proven no match for China's industrial dominance.

In solar, some half of IRA-funded projects are China-backed, because of a dearth of alternatives as well as a dearth of guardrails.

In critical materials, like graphite, government loans and grants have proved insufficient in getting domestic industry off the ground, in a market, and amid a customer set that China controls.

The problem is that the U.S. and China are playing different games. Beijing isn't competing to be a first mover in developing the best, newest technology. Beijing is competing to control markets and resources. The U.S. can pour billions of dollars into developing the best new chip design technology, but what use is that if those chips can only be made with Chinese products or equipment or have to be sold into the Chinese market?

The U.S. can try to impose company and good-level restrictions on China, but what good is that if the industrial ecosystem is so dependent on China that it will do Beijing's bidding?

The problem is also that the U.S. arsenal, both offensive and defensive, is out of touch with the reality of China's tools. Often U.S. discussions of Chinese industrial policy reduce it to relatively direct, tactical measures to, for example, subsidies, government grants, investment from government funds, talent programs, preferential policies on loans. All of those are important. Made in China 2025 lists each one of them.

But Made in China 2025 also describes a larger, more systemic program to, quote, "shape incentives and constraint mechanisms," to create the conditions for capital to fund the companies and the research that Beijing wants it to, for upstream and downstream companies and research entities in China to work together, for foreign research and development to flow into China, not the other way around.

This is how Beijing's industrial policy really works. China is not a market economy. Market forces do not decide how Chinese companies invest or partner. Rather, China builds those guardrails and incentives and then a tamed set of market forces operate within them, in the interest not of free trade or exchange, reciprocity or prosperity, but in the interest of Beijing's strategic ambitions. This is the state-led, enterprise-driven model, and this is how Beijing deploys its industrial offensive.

In an attempt to respond, Washington has thus far reacted. Washington has let Beijing shape the direction of the competition, and Washington has resorted to mirroring its adversary, and mirroring only that first tactical set of tools, like subsidies, as well as a version of those that is far less effective than the PRC's. In doing so, America has pitted its weaknesses against its adversary's strengths.

An effective U.S. policy starts from American strengths, which are market forces and market size, and an effective U.S. policy stops trying to outrun and starts tackling China.

Beijing's industrial policy crafts those incentives and constraints and then lets neutered market forces operate within them. A U.S. policy for industry can succeed by building real, system-level guardrails against the CCP and its distortive effects, and then letting free market forces operate within those defenses -- in other words, by removing the distorted agent from a system that without it actually works.

The first step in such a policy is real, system-level action that alters China's distortive role in the international trade system, to level the playing field. The United States should revoke

China's Permanent Normal Trade Relation status. Additional and supporting measures can also be effective here. Subsidies, for instance, if they are appropriately enforced, and if they target not only Chinese entities in China but also those that have localized production abroad. Also vast expansions of domestic content requirements and prohibitions on any entities that have investment, operational, or licensing ties to China from receiving any government incentives.

Across the board, Washington needs to ensure the compliance of its allies and partners as well as the private sector, and Washington can do this by making access to the U.S. market contingent on such compliance.

Second, the U.S. government will never be able effectively to pick winners and losers. However, the government can and should establish the conditions for domestic industry to thrive. After decades of neglect, the U.S. should rebuild the infrastructure necessary for domestic production, that includes energy, upstream inputs, a skilled workforce, and a permissive regulatory environment.

In the decade since Beijing issued Made in China 2025, the U.S. has made really remarkable progress at recognizing the threat posed by the CCP, and the U.S. has made a remarkable lack of progress in responding effectively. This establishes the stakes for the decade ahead. Beijing has the momentum. Beijing has control of the battlefield and the players on it. The CCP is on its way toward a clean sweep. The U.S. needs to start competing strategically with American strengths. Our ability to do so will determine where the future is made.

Thank you for the opportunity to testify today.

PREPARED STATEMENT OF EMILY DE LA BRUYÈRE, CO-FOUNDER, HORIZON ADVISORY, AND SENIOR FELLOW, FOUNDATION FOR DEFENSE OF DEMOCRACIES

U.S.-China Economic and Security Review Commission

Made in China 2025—Who Is Winning?

Panel: The Next Decade of U.S.-China Tech Competition

EMILY DE LA BRUYÈRE

Co-Founder
Horizon Advisory

Senior Fellow
Foundation for Defense of Democracies

Washington, DC
February 6, 2025

Hearing co-chairs Schriver and Kuiken, distinguished commissioners and staff of the U.S.-China Economic and Security Review Commission, and fellow panelists, it is an honor to participate in today's hearing.

China uses its industrial capacity to project power. Beijing sees industrial strength not only as a means to bolster the nation's military capabilities, economic prowess, and social system. Industrial strength also secures the asymmetric dependence of foreign nations and companies. The Chinese Communist Party (CCP) leverages industrial power for strategic ends, to tie foreign incentives to China's own — and, ultimately, to shape global markets, politics, information, technology, in a self-reinforcing fashion, industry itself.

Beijing makes no secret of its ambitions. The first paragraph of the Made in China 2025 national plan explains that "building an internationally competitive manufacturing industry is the only way for China to enhance its comprehensive national strength, safeguard its national security, and build a world power." The plan also calls, repeatedly, for promoting the People's Republic of China's (PRC's) "military-civil fusion" strategy. Military-civil fusion entails at a first level the exchange of civilian and military technology and resources. At a next level, it entails the conversion of commercial and industrial positioning into offensive power.

China's grand industrial project is, today, at a critical juncture. The Made in China 2025 plan issued in 2015 was a ten-year program that initiated China's "manufacturing great power strategy." But Made in China 2025 constitutes only the first stage of that campaign. It is the first of three, sequential, ten-year programs intended to build China into the world's dominant industrial power by the country's centennial, in 2049.

That timing is important because of the auspicious nature of the year 2049 for the CCP. The timing is also important because of the stakes of the present. Beijing sees the current moment as a critical juncture for industrial, and therefore strategic, competition. The information technology revolution is upsetting the international industrial order. This creates a rare opportunity for a disruptor to compete for supremacy in and write a fresh set of rules for that order. Beijing is ready. It has built the requisite industrial base, international influence, and technological sophistication. But opposing forces demand decisive action: Developed countries, chief among them the United States, are working to re-industrialize and resist Beijing from the top down — even as developing countries challenge China's manufacturing prowess from the bottom up.

Beijing believes that if it can neutralize those opposing forces and marshal sufficient domestic industrial power, it will cement control over the information era. But if Beijing fails to do so, the U.S.-led system will prevail. There will be no second chance. Or, at least, there will be no second chance until the next industrial or global revolution. And who knows when that will happen, or how China will be positioned when it does. Hence Xi Jinping's frequent talk of "changes that come only once in a century."

Beijing has articulated the challenge, and opportunity, at hand. But the stakes are highest for the United States. If the Chinese Communist Party realizes its industrial ambitions — those outlined in Made in China 2025 and that will define the subsequent stages of Beijing's Manufacturing Great Power program — the U.S. industrial and defense industrial bases will find themselves entirely dependent on China. Should that happen, Beijing will control the prosperity and security that depend on those bases. Beijing will be able to decide which companies win or lose; which have access to critical technology, for example, or inputs and markets. This power will grant the CCP influence over U.S. politics and society, because those depend on and are shaped by markets. And in a modern technological environment, China's control over American industry will also grant it control over American information.

Ten years ago, when Beijing issued Made in China 2025, to describe this future risk was to sketch the fantastic; to paint an abstract, in many ways unimaginable threat. Today, there is nothing abstract about it. Made in China 2025 established telecommunications equipment — including 5G technology, routing and switching technology, new generation base stations, and network security more generally — as a priority field within information technology.[1] Today, the PRC has infiltrated basically the entire U.S. telecommunications network.[2]

Made in China 2025 also established the new materials industry as a priority and included within it "strategic frontier materials" ranging from nanomaterials to graphite. Graphite is a critical material input for batteries. In 2015, China produced about 65 percent of the world's graphite. Over the decade since, global demand for the material has skyrocketed. China's production has increased even faster: The PRC produces about four times more graphite today than it did in 2015, accounting for some 80 percent of the world's total. China's graphite dominance allows Beijing to set international prices. It also affords Beijing leverage over the U.S. battery companies that depend on graphite supply — and over their downstream customers.[3]

This leverage and its consequences are playing out in real time. The nascent U.S. domestic graphite industry recently brought an anti-dumping and countervailing duty petition against subsidized Chinese manufacturers. Those opposing the petition? U.S.-based battery manufacturers, because they enjoy access to low-cost Chinese graphite. In taking this stance, U.S.-based battery manufacturers are effectively aligning with Chinese interests. This despite the fact that batteries, as well as their downstream applications like electric vehicles, are also on the Made in China 2025 agenda. And in both sectors — not to mention the ecosystem of intelligent systems like smart navigation and lidar connected to them — Beijing's rising market share poses

[1] Rush Doshi, Emily de La Bruyere, Nathan Picarsic, and John Ferguson, "China as a 'Cyber Great Power:' Beijing's Two Voices in Telecommunications," The Brookings Institution, April 2021.
[2] Dustin Volz et al., "How Chinese Hackers Graduated from Clumsy Corporate Thieves to Military Weapons," *The Wall Street Journal,* January 4, 2025.
[3] "The China Hazard: How China Strategically Controls the Global Battery Supply Chain," Horizon Advisory, October 2024.

a clear, long-term threat to non-Chinese industry. Reliance begets co-option, long-term interests be damned.

Made in China 2025 also prioritizes the semiconductor industry. Specific emphases therein include high-density packaging, also known as advanced packaging. Packaging is generally seen as a low value-add and therefore relatively unimportant node of the semiconductor value chain. But it is an indispensable one. And advanced packaging — technologies like 2.5D/3D stacking and wafer-level packaging — enables enhanced chip capabilities both at relatively low cost and without the advanced fabrication technologies on which the United States has imposed export controls.

China is the world's dominant player in semiconductor packaging, holding more than a quarter of global market share overall and more than one half in advanced packaging (and growing). This means that even non-Chinese companies — those with advanced technologies that the PRC cannot rival and that are considered to be crown jewels in the U.S.-China semiconductor competition — ship their products to the PRC for packaging. It also means that Beijing is developing and dominating in cost-efficient methods of improving semiconductor capability that evade U.S. and allied technology restrictions.

As those cases indicate, Beijing's industrial offensive has thus far thwarted U.S. efforts to fight back — even in those areas most directly targeted by U.S. policy. In telecommunications, the United States has attempted an unprecedented battery of company-level restrictions: Prohibitions on the purchase of equipment made by and sales of equipment to major Chinese companies like Huawei and ZTE; denials of licenses to the State-owned big three service providers, China Telecom, China Mobile, and China Unicom; and a litany of sanctions. None of those restrictions have stopped Beijing from penetrating U.S. telecommunications networks. Nor has it stopped U.S. companies from relying on, selling to, and lobbying on behalf of both known bad actors and an entire ecosystem of unknown ones, or hidden Huaweis.[4]

In graphite, and the battery sector more generally, the United States has tried support for domestic industry. But that support has been no match for China's dominance, and dominant control over the market. Washington originally banned batteries made with Chinese graphite from receiving Inflation Reduction Act tax credits. But Washington rolled back that ban because the PRC has wiped out alternative sources of supply. Loans and grants for domestic players do little when China has pricing power over their market and that of their customers.[5]

In semiconductors, the United States has invested in advanced downstream technology — and in denying it to China. The CHIPS and Science Act allocated tens of billions of dollars to research, development, and application at the cutting edge of the semiconductor value chain. Washington

[4] Ana Swanson, "How U.S. Firms Battled a Government Crackdown to Keep Tech Sales to China," *The New York Times,* December 12, 2024.
[5] Sybil Pan, "US Delays Ban on Chinese Graphite Batteries while ex-China Suppliers Scrabble to Source Critical Minerals," *Fastmarkets*, May 8, 2024.

has imposed unprecedented restrictions on the PRC's access to U.S. and allied semiconductor technology. All the while, Beijing has continued to cement a stranglehold over the inputs, processes, and markets on which those downstream technologies depend; to develop non-technologically exquisite, but effective, processes that evade U.S. restrictions; and, of course, to use its global presence, its industrial influence, and loopholes in U.S. policy to maintain access to any actors or technologies on which it actually depends.

The problem is that the United States and China are playing different games. Beijing isn't competing to be a first mover to develop the best technology. Beijing has a different goal. It is competing to control markets and resources. The United States can pour billions into the newest chip design methods, but that's of little use if those chips can only be made with Chinese inputs or equipment or have to be sold into the Chinese market. The United States can try to impose targeted restrictions on Chinese goods and entities. But that's of little use if the industrial ecosystem is so dependent on China that it will do Beijing's bidding and provide entry points for the PRC.

The problem is also that Washington's tools are out of touch with the arsenal at Beijing's disposal. Often, U.S. discussions of Chinese industrial policy reduce it to targeted, direct forms of state support: tactical measures like subsidies, tax breaks, favorable loans, connections to government research, and investment from government funds. All are important. The Made in China 2025 plan lists each of them. It explains that they are to be used to support, in particular, major large-scale industrial champions; specialized companies with, or positioned to secure, outsized market share in key nodes of key value chains; and companies claiming or building foreign outposts and influence.

But Made in China 2025 also describes a larger, more systemic program to "shape incentives and constraint mechanisms" — to create the conditions for social capital to fund the companies Beijing wants to support; for upstream and downstream, companies and research entities to work together; for foreign players to bring research and development into China and not the other way around.

That is how Beijing's industrial policy really works. China is not a market economy. Market forces do not decide how Chinese companies invest or partner. Rather, Beijing builds a system of guardrails and inducements, or "incentives and constraints." Within that system, a tamed set of market forces work to the benefit not of free trade or exchange, prosperity or reciprocity, but of China's strategic interests. This is the State-led, enterprise-driven model. And this is how Beijing deploys its industrial offensive.

In an attempt to respond, Washington has been reactive. Washington has both let Beijing determine the direction of the competition and has resorted to mirroring its adversary. In that mirroring, Washington has relied just on that first set of tactical measures, like subsidies, and a version of them that is far less effective than the PRC's. In doing so, America has pitted its weaknesses against China's strengths.

An effective U.S. policy starts from American strengths — market size and market forces. And an effective U.S. policy stops trying to outrun and starts tackling China. Beijing's industrial policy crafts constraints and incentives and then lets neutered market forces operate within their confines. A U.S. policy for industry can succeed by building real, system-level barriers against the Chinese Communist Party and then letting undistorted market forces operate within those barriers — by, in other words, removing the distortive agent from a system that, without it, actually works.[6]

The first step in such a policy is action that systemically alters China's role in the international trade system — as befits a distortive, non-market actor — to level the playing field. The United States should revoke China's Permanent Normal Trade Relations (PNTR) status. Additional and supporting measures can also be effective: If sufficiently high and properly enforced, tariffs can do the trick, especially if they target not only goods made in China but also those made by Chinese entities that have "localized" abroad. Across the board, the United States needs to guarantee that allies and partners, companies, and investors comply. Washington can do so by making access to the U.S. market contingent on such compliance and signaling long-term resolve.

Second, the U.S. government will never succeed at picking winners and losers. But it can and should create the conditions for industry to thrive at home. After decades of neglect, the U.S. government should re-establish the infrastructure necessary for domestic industry — including through expanded production of domestic energy and upstream inputs, a permissive regulatory environment, and a skilled workforce.

The Made in China 2025 plan is just the first of three, ten-year campaigns through which Beijing intends to cement control over global production, and with it global security and prosperity. In the decade since Beijing issued the plan, the United States has made remarkable progress in recognizing the threat that China poses — and a remarkable lack of progress in responding effectively. This establishes the stakes for the next decade, the 2025 to 2035 period. Beijing has the momentum and control of the battlefield as well as the players on it. The Chinese Communist Party is on a path toward a clean sweep. The United States needs to start competing, strategically, with American strengths. America's ability to do so will determine where the future is made.

Hearing co-chairs Schriver and Kuiken and distinguished commissioners, thank you for the opportunity to testify on this important topic.

[6] Emily de La Bruyere and Nathan Picarsic, "How to Actually Compete with China," *The Spectator,* February 8, 2024.

OPENING STATEMENT OF HANNA DOHMEN, RESEARCH ANALYST, GEORGETOWN UNIVERSITY CENTER FOR SECURITY AND EMERGING TECHNOLOGY (CSET)

COMMISSIONER KUIKEN: Thank you, Ms. de La Bruyère, whose name I am going to continue to butcher, and I apologize.

Ms. Dohmen.

MS. DOHMEN: Hearing Co-Chairs Schriver and Kuiken, distinguished Commissioners and staff, thank you for the opportunity to participate in today's hearing alongside my esteemed panelists.

I am currently a research analyst at the Center for Security and Emerging Technology at Georgetown University, where I research U.S.-China technology competition, semiconductor export controls, and China's science and technology ecosystem. I would like to emphasize that the views I express today are my own.

My testimony focuses on how China's science and technology ecosystem drives innovation in emerging technologies, with a particular focus on the Chinese Academy of Sciences, also known as CAS, and the implications of U.S. semiconductor export controls on China's AI and semiconductor innovation.

Let me begin with CAS's role in China's innovation ecosystem. As one of China's most important science and technology organizations, CAS is tasked with helping the Chinese government realize the objectives of various national policy plans, including Made in China 2025. It promotes these goals through three main functions: advancing research, commercializing technologies, and shaping Chinese S&T policy.

In terms of research advancement, CAS has emerged as China's most prolific producer of STEM research, and has become increasingly competitive globally. Beyond research, CAS has long been an important player in transforming research into commercial applications. The organization supports its spinoff companies and helps bring research breakthroughs to the market through various mechanisms, including through funding, joint research projects, talent development programs, and shared personnel and facilities.

CAS also plays a crucial role in shaping and implementing China's S&T policies through its network of academicians and think tanks.

The CAS model illustrates China's centralized approach to accelerating indigenous innovation, underscoring its strategic focus on achieving self-reliance in critical technology areas like AI and semiconductors. In part, this prompted the U.S. government to increasingly focus on economic security tools to protect U.S. national security and maintain U.S. technological leadership. It is against this backdrop that export controls emerged as the primary tool for slowing China's military modernization and AI development efforts.

Whether these controls will achieve their desired outcomes presents a complex picture and one that is likely too soon to judge. It is important to first recognize that export controls will not prevent all AI development or semiconductor technology innovation in China. Instead, the controls are intended to impose a strategic delay and increase the cost of China's AI development efforts.

In terms of slowing China's military modernization, the controls will likely have a limited impact for a few reasons. One, current weapon systems rely on mature, well-tested chips. Two, not all military AI applications are as compute-intensive as large language models. And three, the PLA's computing needs can largely be met through a combination of legally imported

chips, domestically produced chips, and smuggled chips.

The impact of export controls on China's AI development generally could be more consequential, but this is dependent on a number of interrelated factors. Right now, China's most advanced models, including DeepSeek's R1 are largely relying on U.S.-made chips, including chips that companies stockpiled before the controls took effect. As these stockpiles deplete over the next couple of years, the controls have the potential to create a growing gap between the AI chip quantity and quality inside and outside of China. But that gap will only hold if U.S. export controls on chip manufacturing tools and other measures aimed at slowing China's semiconductor fabrication capacities are effective.

Similar to the stockpiles of AI chips, Chinese equipment firms also stocked up on foreign equipment before controls were implemented. This, once again, imposes a lag between when the controls were implemented and when the controls will bite.

We must also consider China's own innovation capabilities in response. There is no question that the Chinese government's push for self-sufficiency predates U.S. export controls. But by limiting China's access to chips and equipment, export controls are creating an incentive to innovate around controls.

Chinese companies are also pursuing technical strategies such as chiplet packaging and focusing on compute and algorithmic efficiencies to overcome restrictions, as DeepSeek has demonstrated.

That doesn't mean U.S. export controls won't slow China's AI development, but it is also not guaranteed. What it does mean is that the United States must very closely monitor and be aware of AI development trends in China's progress to be able to anticipate policy adjustments, when needed, and increase the effectiveness of the controls while reducing the costs.

Moreover, in order for the broader U.S. export control strategy to work it is critical that the United States clearly articulates the objectives of the export controls to allies, provides evidence that justifies the objectives, and underscores why they are necessary to protect common interests.

Based on these observations I offer three recommendations for policymakers.

First, enhance U.S. open source intelligence capabilities to better understand China's S&T ecosystem and monitor progress. Establishing a new open source science and technology-focused research center would help track global developments and emerging technologies and their implications for U.S. security.

Second, require the Department of Commerce to conduct scenario planning of export control policies. These exercises should include clear articulations of control objectives, analyses of underlying assumptions, and assessments of economic impacts on U.S. firms. Congress should also increase funding for BIS, to expand analytical and enforcement capabilities.

Third, and most importantly, invest in U.S. technological progress. The U.S. government's ability to obstruct China's technological advancement can only go so far. Therefore, policymakers must focus on driving innovation in the next generation of emerging technologies by funding basic research, expanding workforce development programs, and investing in the domestic manufacturing ecosystem.

Thank you for your attention. I look forward to your questions.

PREPARED STATEMENT OF HANNA DOHMEN, RESEARCH ANALYST, GEORGETOWN UNIVERSITY CENTER FOR SECURITY AND EMERGING TECHNOLOGY (CSET)

February 6, 2025

Hanna Dohmen[1]

Research Analyst, Center for Security and Emerging Technology, Georgetown University
Nonresident Fellow, Global China Hub, Atlantic Council

Testimony before the U.S.-China Economic and Security Review Commission

"Made in China 2025—Who is Winning?"

Panel II: "The Next Decade of U.S.-China Tech Competition"

Co-Chair Vice Chair Schriver and Co-Chair Commissioner Kuiken, distinguished Commissioners and staff, thank you for the opportunity to participate in today's hearing. It is an honor to testify alongside the esteemed experts on this panel. I am a research analyst at the Center for Security and Emerging Technology at Georgetown University, where I research U.S.-China technology competition, U.S. semiconductor export controls, the semiconductor supply chain, and China's science and technology (S&T) ecosystem.

Today my testimony will focus on how the Chinese S&T ecosystem is driving innovation in emerging technologies, with a particular focus on (i) the Chinese Academy of Sciences and (ii) implications of U.S. semiconductor export controls, including China's response to these restrictions. I also offer three recommendations for policymakers.

I. The Chinese Academy of Sciences' Role in China's S&T Ecosystem

China's pursuit of technological leadership is a decades-long endeavor that has intensified significantly under President Xi Jinping's leadership. In 2006, former President Hu Jintao launched a national campaign to accelerate indigenous innovation and to reduce China's reliance on foreign technologies, which was formalized in part through the "Medium- to Long-Term Plan for Science and Technology (2006-2020)" (MLP; 国家中长期科学和技术发展规划).[2] This plan set national research priorities, provided R&D funding, and emphasized the importance of "indigenous innovation."[3] The MLP was later reinforced through subsequent policies under President Xi Jinping, including "Made in China 2025" (MIC 2025; 中国制造2025).

[1] The opinions expressed in this testimony are mine only and should not be interpreted as representing those of CSET or the Atlantic Council.

[2] "Outline of the National Medium- and Long-Term Plan for Science and Technology Development" [国家中长期科学和技术发展规划刚要], State Council of the PRC, https://perma.cc/6AE8-BJLY.

[3] Cong Cao, Richard P. Suttmeier, and Denis Fred Simon, "China's 15-year science and technology plan," *Physics Today*, December 2006, https://china-us.uoregon.edu/pdf/final%20print%20version.pdf.

MIC 2025 represents one of China's most comprehensive industrial policy plans to achieve indigenous innovation in ten strategic technology industries.[4] The Plan set out three key milestones: (i) become a major manufacturing power by 2025, (ii) become a global manufacturing power by 2035, and (iii) become a leading manufacturing superpower by 2049.[5] While public discussion of MIC 2025 in China has diminished since 2018, the core objectives remain central to the country's industrial policy and efforts to achieve self-reliance in core technology areas, including semiconductors and artificial intelligence (AI).[6]

The Chinese Academy of Sciences (CAS), in part, is tasked with helping realize the objectives of the MLP, MIC 2025, and subsequent policies.[7] Moreover, it serves as an illuminating case study for understanding how China's state-led innovation ecosystem operates and the level of interconnectedness among its research, commercialization, and policymaking efforts.

CAS is directly managed by the State Council, and its primary responsibilities include advancing China's S&T research capabilities in order to strengthen the national innovation ecosystem and boost the country's technological self-reliance. Since its establishment in 1949, CAS has been instrumental in China's technological advancement, contributing to strategic weapon, space technology, and long-range missile development.[8] CAS oversees 115 research institutes, employs over 60,000 researchers, manages two universities, and has an annual budget of around $23.5 billion.[9] CAS has three key functions: (a) advancing research, (b) commercializing technologies, and (c) shaping Chinese S&T policy.

a. Advancing Research

CAS has emerged as China's most prolific producer of STEM research and has become increasingly competitive on the global stage. CAS institutes now lead all other global research institutions in highly cited STEM papers, with particular strength in the industrial technology

[4] The ten strategic technology industries are: (1) new generation IT, (2) high-end computerized machines and robots, (3) aviation and aerospace equipment, (4) maritime engineering equipment and high-tech ships, (5) advanced rail transportation equipment, (6) new energy vehicles, (7) energy equipment, (8) agricultural machinery and equipment, (9) new materials, and (10) biotechnology, pharma, and high-performance medical devices. PRC State Council, "Notice of the State Council on the Publication of Made in China 2025" [国务院关于印发《中国制造2025》的通知], trans. CSET (CSET, March 8, 2022), https://cset.georgetown.edu/wp-content/uploads/t0432_made_in_china_2025_EN.pdf.

[5] PRC State Council, "Notice of the State Council on the Publication of Made in China 2025."

[6] Alexander Brown and Andreas Mischer, ""Manufacturing Champions" + Equipment renewal + Mobile Internet of Things," MERICS, October 2, 2024, https://merics.org/en/merics-briefs/manufacturing-champions-equipment-renewal-mobile-internet-things.

[7] Richard P. Suttmeier, Cong Cao, and Denis Fred Simon, "'Knowledge Innovation' and the Chinese Academy of Sciences," Science 312, no. 5770 (April 7, 2006): 58–59.

[8] Cole McFaul, Hanna Dohmen, Sam Bresnick, and Emily Weinstein, "Fueling China's Innovation: The Chinese Academy of Sciences and Its Role in the PRC's S&T Ecosystem," CSET, October 2024, https://cset.georgetown.edu/publication/fueling-chinas-innovation-the-chinese-academy-of-sciences-and-its-role-in-the-prcs-st-ecosystem/.

[9] CAS, "Chinese Academy of Sciences 2022 Budget" [中国科学院 2022 年部门预算], trans. CSET (CSET, February 27, 2024) https://cset.georgetown.edu/wp-content/uploads/t0585_CAS_budget_2023_EN.pdf; McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."

field of study.[10] In 2021, 35 percent of papers published by CAS institutes focused on the field of industrial technology.[11] Within this field, CAS institutes published most frequently in the subfield of automation and computer technology, which includes AI-related research, followed by radio electronics and telecommunications technology, and chemical engineering (see Appendix).[12] The number of highly cited STEM papers from CAS institutes has more than doubled between 2012 and 2022, while the number of highly cited CAS researchers has grown from fewer than 40 in 2014 to over 200 in 2022.[13] While bibliometric data is an imperfect proxy for impact, this change nonetheless reflects a notable increase in China's research output and quality.

b. Fostering Commercialization

One of the core functions of CAS is to commercialize technologies that arise from its research. The organization plays an important role in contributing to the development of Chinese technology companies and working toward self-sufficiency in emerging technologies.[14]

The centrality of commercialization to CAS's mission today is evidenced by CAS's 13th Five-Year Plan (2016-2020).[15] The plan stipulates that over the five-year period, the organization will incubate more than 5,000 companies, strengthen globally competitive enterprises and "hidden champion" enterprises, and provide technology development and consulting services for at least 20,000 companies.[16]

One of the main mechanisms by which CAS works to advance technological progress is through investing in research teams at its institutes, universities, and labs. Some of China's most well-known technology companies are spin-offs from CAS research institutes and universities, which CAS supported financially, including Lenovo and iFLYTEK.[17] CAS has various financial institutions that support its commercialization efforts, including asset management firms, venture capital (VC) firms, and university and research institute investment arms.

For instance, Chinese Academy of Sciences Holding Co. (中国科学院控股有限公司; CASH) is CAS's primary asset management firm, which invests in a broad range of S&T fields. Over the last decade, CASH has provided funding for and invested in a number of key Chinese technology companies at various stages of the startup life cycle, from the seed stage to the exit phase. For example, in 2014, together with CAS-spin off and supercomputer manufacturer Sugon, CASH

[10] In a CSET report titled "Fueling China's Innovation: The Chinese Academy of Sciences and Its Role in the PRC's S&T Ecosystem," we defined highly cited papers as papers in at least the 90th percentile of citations in their field in a given year; McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."
[11] CAS research institutes are the organization's network of research centers conducting basic and applied research across a variety of critical fields in science and technology.
[12] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."
[13] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."
[14] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."
[15] CAS, "Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan" [中国科学院'十三五'发展规划纲要], trans. CSET (CSET, October 17, 2022), https://cset.georgetown.edu/wp-content/uploads/t0454_CAS_13th_5YP_EN.pdf.
[16] CAS, "Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan."
[17] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."

provided seed funding for Hygon, a Chinese CPU design company.[18] This demonstrates that successful spin-off companies also reinvest in the CAS ecosystem and support other promising companies.

CAS additionally operates a number of VC arms, including CAS Investment Management Co. (中国科技产业投资管理有限公司) and CAS Star (中科创星).[19] CAS Investment Management Co. primarily makes early- and late-stage VC investments in emerging technologies, including biotechnology, AI, and semiconductors.[20] CAS Star appears to be one of the most active CAS investors, which focuses on early-stage investments in emerging technologies as well. CAS Star not only provides investment opportunities, but it is also committed to integrating those early-stage investments with research institutions and post-investment services.[21] As of April 2024, CAS Star managed four funds and invested in more than 470 technology companies, including Zhipu AI, one of China's leading AI startups.[22]

CAS universities and individual research institutes have their own investment arms that support their organization's commercialization endeavors. The University of Science and Technology of China (USTC) manages an investment arm called USTC Holdings Co., which manages the university assets and funds startups. For example, in 2019, USTC Holdings provided VC funding for Origin Quantum, which is a quantum computing startup founded by researchers from USTC.[23] Similarly, the CAS Institute of Computing Technology also manages an investment arm, which has helped the institute launch a number of China's computing and semiconductor companies, including Sugon, Cambricon, and CPU-designer Loongson.[24]

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[18] "Leading Chinese CPU Firm Hygon Listed to Shanghai's STAR Market," Pandaily, August 12, 2022, https://pandaily.com/leading-chinese-cpu-firm-hygon-listed-to-shanghais-star-market/; The U.S. Department of Commerce's Bureau of Industry and Security (BIS) added both Sugon and Hygon to the Entity List in 2019; BIS, "Addition of Entities to the Entity List and Revision of an Entry on the Entity List," *Federal Register* 84 FR 29371 (June 24, 2019), https://www.federalregister.gov/documents/2019/06/24/2019-13245/addition-of-entities-to-the-entity-list-and-revision-of-an-entry-on-the-entity-list.

[19] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation;" "About CAS Star" [关于中科创星], CAS Star, https://archive.ph/t6BKO.

[20] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."

[21] "About CAS Star."

[22] "About CAS Star;" BIS added Zhipu AI to the Entity List in 2025; BIS, "Addition of Entities to and Revision of Entry on the Entity List," *Federal Register* 90 FR 4617 (January 16, 2025), https://www.federalregister.gov/documents/2025/01/16/2025-00704/addition-of-entities-to-and-revision-of-entry-on-the-entity-list.

[23] Li Xiaoyang, "NPC deputy contributes to quantum computing research," Beijing Review, March 04, 2023, https://www.bjreview.com/Special_Reports/2023/NPC_CPPCC_Sessions_2023/From_the_Magazine/202303/t20230306_800324282.html.

[24] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation;" BIS added ICT to the Entity List in 2022, Loongson in 2023, and USTC in 2024; BIS, "Additions and Revisions to the Entity List and Conforming Removal From the Unverified List," *Federal Register* 87 FR 77505 (December 19, 2022), https://www.federalregister.gov/documents/2022/12/19/2022-27151/additions-and-revisions-to-the-entity-list-and-conforming-removal-from-the-unverified-list; BIS, "Additions and Revisions of Entities to the Entity List," *Federal Register* 88 FR 13675 (March 6, 2023), https://www.bis.doc.gov/index.php/documents/regulations-docs/federal-register-notices/federal-register-2023/3245-88-fr-13673/file; BIS, "Additions of Entities to the Entity List," *Federal Register* 89 FR 41886 (May 14, 2024), https://www.federalregister.gov/documents/2024/05/14/2024-10485/additions-of-entities-to-the-entity-list.

Beyond providing funding for tech enterprises, CAS provides other services designed to promote company development through joint research projects, talent development programs, shared personnel and facilities, access to technical expertise, and other intangible benefits. For instance, the Legend Institute (联想学院), an organization set up between CAS and Lenovo, focuses on exploring S&T training programs and industry-academic-research institute (产学研) integration.[25] To further promote such integration, CAS also constructed various "Technological Innovation and Industrialization Alliances" ("技术创新与产业化联盟"), including the "Advanced Computing Alliance" ("先进计算技术联盟"). This alliance is focused on combining the resources of Sugon and seven CAS research institutes to promote Sugon's competitiveness in high-performance computing and cloud computing.[26]

These examples illustrate how CAS not only promotes S&T research but also fosters commercialization of technologies through an interconnected network and maintains close connections with successful CAS spin-offs that feed back into the Chinese research ecosystem.

c. Shaping and Implementing S&T Policy

CAS has played an important role in shaping and implementing some of China's most significant S&T policy initiatives, and the central government considers CAS to be a key advisory body on innovation policy.[27] The organization played a crucial role in establishing the 863 Program (National High-Tech Development Plan), which advanced progress in supercomputing and aerospace technologies, and the 973 Program, which provided essential funding for basic research until its integration into China's National Key R&D Program in 2016. [28]

The influence of CAS extends beyond direct policy formation through its network of academicians (院士) and associated think tanks. The Chinese Academy of Sciences Academic Divisions (CASAD; 中国科学院学部), established in 1955, serves as a key advisory body to the State Council and other government agencies on S&T policy formation and coordination. Since 2019, CASAD has conducted joint research with the National Natural Science Foundation of China (NSFC) to study development paths for emerging technologies critical to China's development goals.

Additionally, in 2016, CAS founded the Institutes of Science and Development (CASISD; 中国科学院科技战略咨询研究院), which is focused on supporting academicians and providing strategic consultations to the central government by integrating CAS research resources.[29] This organization is intended to improve China's S&T policymaking capabilities.[30]

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[25] CAS, "Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan;" "中国科学院联想学院," Baidu, https://perma.cc/H5EC-975B.
[26] "先进计算技术联盟," CAS Holdings, October 21, 2015, https://perma.cc/K8KB-FREG.
[27] Xiaoxuan Li, Kejia Yang, and Xiaoxi Xiao, "Scientific Advice in China: The Changing Role of the Chinese Academy of Sciences," Nature, July 12, 2016, www.nature.com/articles/palcomms201645.
[28] McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."
[29] Li, Yang, and Xiao, "Scientific Advice in China: The Changing Role of the Chinese Academy of Sciences."
[30] "National High-End Think Tank Construction Pilot Project" [国家高端智库建设试点], China Development Institute, accessed January 23, 2024, https://perma.cc/JA9N-NUXU.

CAS, an interconnected research, commercialization, and policymaking organization, is a useful model for understanding China's state-led innovation ecosystem and its implementation of policies such as MIC 2025. This model, undoubtedly, has led to significant innovation successes, but it has also been plagued by inefficiencies. To what extent China will continue to make scientific and technological advancements remains uncertain. What is certain, however, is that China's innovation capacity should not be underestimated.

II. Effectiveness of Slowing China's Technological Progress Through Export Controls

China's highly-centralized approach to achieving technological self-sufficiency is epitomized by institutions like CAS and supported by massive state investment. It was against this backdrop that the United States began to restrict Chinese access to U.S. technologies, know-how, and capital. The United States has implemented various economic security tools aimed at maintaining U.S. technological leadership, particularly in AI and semiconductors. Export controls emerged as the primary tool for slowing China's military modernization and technological development efforts in recent years. Note that by themselves, export controls only serve to delay—not prevent—China's technological advancement. To achieve the goal of maintaining (and growing) U.S. technological leadership, export controls must be accompanied by concerted efforts to accelerate American innovation. This way, when China does catch up to current U.S. technology levels, we have already moved on to the next technological breakthrough.[31]

At a high level, regulations are being used to restrict both advanced chips used in the development of AI models, in particular large language models (LLMs), and the semiconductor manufacturing equipment used to make those chips from being exported to China. Between 2022 and 2024, the Biden administration issued annual regulatory updates to strengthen restrictions, close gaps, and adjust policies as the technologies advanced.[32]

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[31] Hanna Dohmen, Jacob Feldgoise, and Charles Kupchan, "The Limits of the China Chip Ban," *Foreign Affairs*, July 24, 2024, https://www.foreignaffairs.com/china/limits-china-chip-ban.

[32] The focus of this written testimony is on the annual updates to the advanced computing and semiconductor manufacturing equipment rules. It does not cover the Framework for Artificial Intelligence Diffusion issued on January 15, 2025 because it has not yet taken effect. If and when it takes effect will be determined by the Trump administration; BIS, "Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items; Supercomputer and Semiconductor End Use; Entity List Modification," *Federal Register* 87 FR 62186 (October 13, 2022), https://www.federalregister.gov/documents/2022/10/13/2022-21658/implementation-of-additional-export-controls-certain-advanced-computing-and-semiconductor; BIS, "Implementation of Additional Export Controls: Certain Advanced Computing Items; Supercomputer and Semiconductor End Use; Updates and Corrections," *Federal Register* 88 FR 73458 (October 25, 2023), https://www.federalregister.gov/documents/2023/10/25/2023-23055/implementation-of-additional-export-controls-certain-advanced-computing-items-supercomputer-and; BIS, "Export Controls on Semiconductor Manufacturing Items," *Federal Register* 88 FR 73424 (October 25, 2023), https://www.federalregister.gov/documents/2023/10/25/2023-23049/export-controls-on-semiconductor-manufacturing-items; BIS, "Foreign-Produced Direct Product Rule Additions, and Refinements to Controls for Advanced Computing and Semiconductor Manufacturing Items," *Federal Register* 89 FR 96790 (December 5, 2024), https://www.federalregister.gov/documents/2024/12/05/2024-28270/foreign-produced-direct-product-rule-additions-and-refinements-to-controls-for-advanced-computing.

Whether export controls will be effective at achieving their desired outcomes is a complicated question. Too often it is portrayed as a binary answer, but the reality is that the story is much more complex. I attempt to disentangle some of the overlapping layers below, recognizing that this is a simplified snapshot of an emerging, complicated picture. Moreover, it is worth noting that export controls are designed to impose a strategic delay and increase the costs of China's self-sufficiency efforts.[33] Export controls cannot be expected to prevent all AI development and innovation in China. Therefore, making assessments of the effectiveness of export controls requires a wide-angle lens, not a microscope.

Under the Biden administration, the controls had two distinguishable objectives. First, the U.S. government sought to slow the PLA's modernization capabilities. Second, the U.S. government sought to slow China's development of AI and thereby maintain U.S. technological superiority. Whether the controls will be effective, however, depends on which objective is in focus.

a. Slowing China's Military Modernization

In terms of slowing Chinese military modernization, the controls' impact appears limited for a number of reasons. First, most current weapons systems rely on mature, well-tested chips manufactured using less advanced equipment, which are not subject to current restrictions.[34] Second, not all AI technologies are as compute-intensive as large language models (LLMs). In fact, computer vision models, used for surveillance and threat detection, require less compute than LLMs. Third, while advanced chips do have some military applications—and may have more in the future, particularly in areas like AI-enabled decision making and data processing—the PLA's computing needs can largely be met through a combination of legally imported lower-performing chips, domestically produced chips, and smuggled chips.

The controls could force the Chinese government to devote more resources to diverting controlled chips to China or training LLMs on less advanced chips, thereby driving up the costs of military modernization. However, the Chinese government has a proven track record of expending the resources needed to pursue its strategic objectives. Ultimately, it will be very difficult for export controls to substantially slow the PLA's development and adoption of AI.

b. Slowing China's AI Development and Deployment

The impact of export controls on China's AI advancement presents an even more complex picture, but one that is likely to be more consequential. While China is making progress in pushing frontier AI development and gaining international recognition for its progress, it is too soon to judge whether export controls will be effective. Currently, some of China's most advanced models are still using U.S.-made chips, whether legally imported chips below the export control thresholds, ones that companies stockpiled before controls went into effect, or

[33] Emily S. Weinstein, "Testimony before the U.S.-China Economic and Security Review Commission Hearing on "Challenges from Chinese Policy in 2022: Zero-COVID, Ukraine, and Pacific Diplomacy," Center for Security and Emerging Technology, August 3, 2022, https://cset.georgetown.edu/publication/emily-weinsteins-testimony-before-the-u-s-china-economic-and-security-review-commission-2/.
[34] "Large Investments by Aerospace and Defense Industries in Microelectronics Are the New Normal," Sourceability, February 14, 2024, https://perma.cc/T6JU-5T7Y.

illegally imported chips.[35] However, stockpiles of chips that China legally imported before U.S. controls took effect will likely last them for the next few years. That is likely when the controls will start to bite more significantly, increasing the gap between the quantity and quality of AI chips available inside and outside of China. Assuming that compute scaling laws—the idea that more compute leads to improved model performance—hold for the foreseeable future, China's demand for chips to develop and deploy AI will likely outstrip its domestic AI chip manufacturing progress by that time.

However, ensuring that efforts to slow China's AI development and deployment succeed will depend highly on the effectiveness of export controls on chip manufacturing tools. Currently, U.S. and allied controls on semiconductor manufacturing equipment are likely more effective than the controls on chips themselves, in part because of the Biden administration's multilateral approach. The United States, together with the Netherlands and Japan, have imposed strict controls on the equipment needed to manufacture advanced-node chips. To be sure, Chinese chip designers like Huawei's HiSilicon have made progress in chip design, and Chinese chip manufacturers have demonstrated an ability to fabricate 7nm chips, albeit at production yields far below industry standards.[36] However, their fabrication capabilities remain heavily dependent on foreign equipment. Similar to the stockpiles of AI chips that Chinese companies built up prior to the controls, Chinese semiconductor manufacturing companies also stocked up on semiconductor manufacturing equipment before allied controls were implemented.[37] This, once again, imposes a lag between when the controls were implemented and when the controls will bite.

c. China's Response

As shown above, the Chinese government's push for self-sufficiency in the semiconductor industry predates U.S. export controls. Given the billions of dollars in investments, public-private partnerships, and other government initiatives aimed at fostering self-sufficiency, China's domestic semiconductor industry was poised to make progress. However, prior to U.S. export controls on China's semiconductor industry, the Chinese government fought against the strong pull of commercial incentives. Chinese fabrication plants preferred to use more sophisticated and reliable equipment from abroad, Chinese designers preferred to manufacture their chips at the best plants in Taiwan and South Korea, and Chinese consumers preferred to use the highest-performance chips designed by Nvidia and other foreign firms.

Now, by limiting China's access to foreign-made chips and equipment to make chips, export controls are creating increased demand for indigenous Chinese equipment, fabrication capacity, and AI chips. This is putting pressure on Chinese companies to invest in domestic industry and join forces with their domestic partners to try to break through key chokepoints in the semiconductor supply chain. These market conditions drive revenue to domestic firms, which will in turn allow these companies to invest more in research and development.

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[35] "DeepSeek-V3 Technical Report," DeepSeek, https://github.com/deepseek-ai/DeepSeek-V3/blob/main/DeepSeek_V3.pdf.
[36] Jacob Feldgoise and Hanna Dohmen, "Pushing the Limits: Huawei's AI Chip Tests U.S. Export Controls," Center for Security and Emerging Technology, June 17, 2024, https://cset.georgetown.edu/publication/pushing-the-limits-huaweis-ai-chip-tests-u-s-export-controls/.
[37] Jacky Wong, "China Is Stockpiling for Next Phase of the Chip Wars," *The Wall Street Journal*, February 26, 2024, https://www.wsj.com/finance/stocks/china-is-stockpiling-for-the-next-phase-of-the-chip-wars-3a5b2af6.

Moreover, Chinese companies are pursuing several technical strategies to overcome restrictions. In chip manufacturing, companies are increasingly turning to chiplet packaging, connecting multiple less powerful chips to create higher-performing packages capable of training and using AI models.[38] This approach helps reduce design and manufacturing costs while working within current technical constraints.

In the AI domain, Chinese AI companies have demonstrated significant progress in LLM training, as evidenced by DeepSeek's latest open-source model.[39] DeepSeek researchers have shown success in optimizing chip-to-chip communication and innovating training methods to effectively train an advanced reasoning model on limited hardware.[40] This suggests that Chinese AI companies could continue to push AI advancements using such engineering techniques, potentially undermining the controls on chips.

d. Multilateral Approach to Export Controls

It is undisputed that export controls are most effective when implemented multilaterally. The U.S. export control strategy under the Biden administration was enhanced by successful multilateral coordination with key allies, particularly Japan and the Netherlands. As the export control strategy becomes more important in managing the geopolitical implications of AI development, so does allied buy-in. However, the current approach, one centered on diplomatic leverage and rule-by-rule persuasion, is unlikely to be sustainable or effective in the long-run. In order for the broader U.S. export control strategy to work, it is critical that the United States clearly articulates the objectives of the export controls to allies, provides evidence that justifies the objectives, and underscores why they are necessary to protect *common* interests.

Export controls have traditionally been used to control the development, production, and use of a weapon. As Kevin Wolf has pointed out to the Commission previously, the messaging thus far has fallen short of articulating and convincing some allies of the identifiable relationship between the controls on chips and semiconductor manufacturing equipment and the risk downstream technologies like AI pose.[41] Further work must be done to provide evidence and systematically engage with allies on why such controls are needed.

III. Recommendations for Future U.S. Policy

China's whole-of-nation approach to innovation and technology development, exemplified by institutions like CAS, demonstrates both the scale and sophistication of its technological

[38] Jane Lee and Eduardo Baptista, "Chip wars: How 'chiplets' are emerging as a core part of China's tech strategy," July 13, 2023, https://www.reuters.com/technology/chip-wars-how-chiplets-are-emerging-core-part-chinas-tech-strategy-2023-07-13/.
[39] "DeepSeek-V3 Technical Report."
[40] "DeepSeek-V3 Technical Report."
[41] Kevin Wolf, "Testimony before the US-China Economic and Security Review Commission Hearing on Key Economic Strategies for Leveling the US-China Playing Field: Trade, Investment, and Technology," Center for Security and Emerging Technology, May 23, 2024, https://www.uscc.gov/sites/default/files/2024-05/Kevin_Wolf_Testimony.pdf.

ambitions. While U.S. export controls may temporarily slow and impose costs on China's AI advancement, they are unlikely to significantly impede its military modernization. Although the United States currently maintains a competitive advantage in semiconductor technology and AI, China's demonstrated innovation capabilities suggest this lead is not guaranteed. Understanding China's innovation ecosystem and how it mobilizes resources, like CAS, to drive national policies is therefore critical. Moving forward, it is important that the United States complement its strategy of restricting technology, capital, and know-how to China with investments in domestic technology development to maintain U.S. technological superiority in the long run.

To conclude, I offer three recommendations for policymakers:

1. **Strengthen Evidence-Based Assessments of China's Technological Progress**

To write effective regulations, U.S. policymakers need accurate, evidence-based assessments of China's technological progress. The United States should enhance its open-source intelligence (OSINT) collection and analysis capabilities to help augment the government's understanding of China's S&T ecosystem and monitor progress in semiconductor technology and AI.[42] As CSET researchers have recommended before, establishing a new, open-source science and technology focused research center would help monitor global developments in emerging technologies and their implications for U.S. national and economic security.[43]

2. **Require the Department of Commerce to Conduct Scenario Planning of Export Control Policies**

Congress should require the Department of Commerce to institute scenario planning exercises before implementing new export controls. These exercises should include clear articulations of control objectives, analyses of underlying assumptions, assessments of economic impact on U.S. and allied firms, evaluations of potential Chinese countermeasures and adaptations, and considerations of near- and long-term consequences. Additionally, BIS should conduct regular post-implementation assessments that track progress toward stated control objectives, impact on China's semiconductor manufacturing equipment industry, developments in China's semiconductor fabrication capabilities, and advancements in China's AI sector.

To support these expanded responsibilities, Congress should increase funding for BIS to expand analytical and enforcement capabilities, strengthen monitoring and compliance programs, enhance coordination with international partners, and improve technical expertise in emerging technologies. These requirements would ensure more strategic and effective implementation of export controls as well as continued evaluation and monitoring of controls while providing Congress with better oversight of their impact and effectiveness.

[42] Owen J. Daniels, "CSET Analyses of China's Technology Policies and Ecosystem: The PRC's Efforts Abroad," (CSET, September 2023), https://cset.georgetown.edu/publication/the-prcs-efforts-abroad/.
[43] Daniels, "CSET Analyses of China's Technology Policies and Ecosystem: The PRC's Efforts Abroad."

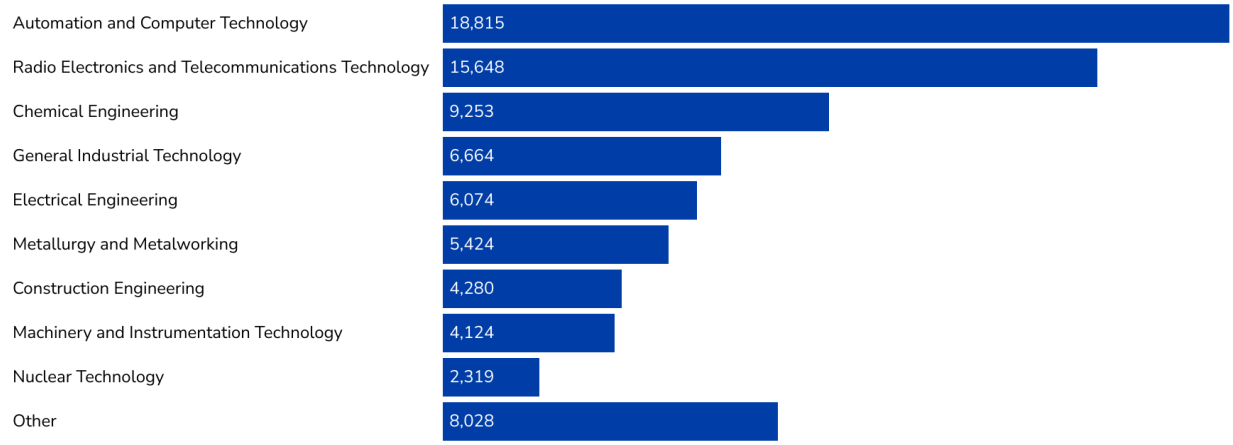
3. Invest in U.S. Technology Progress

Driving innovation domestically should be the top priority of U.S. policy when it comes to competing with China. The bottom line is that the U.S government ultimately has only a limited capability to obstruct China's technological advance on a level that will be geopolitically consequential. What U.S. policymakers can significantly influence, and where they should focus their efforts, is on the United States' own innovation capacity. The United States must drive innovation in the next generation of emerging technologies by funding basic research, expanding workforce development programs, and investing in the domestic manufacturing ecosystem.

Congress has a crucial role to play in shaping this approach through legislation that supports domestic innovation and promotes the development of next-generation technologies. By taking action in these areas, Congress can help ensure that the United States maintains its technological leadership while effectively managing the challenges posed by China's technological advancement.

IV. Appendix

Figure 1: CAS Institutes Industrial Technology Papers by Subfield, 2010-2021



Source: CNKI[44]

[44] Figure 5 in CSET Report "Fueling China's Innovation: The Chinese Academy of Sciences and Its Role in the PRC's S&T Ecosystem;" McFaul, Dohmen, Bresnick, and Weinstein, "Fueling China's Innovation."

OPENING STATEMENT OF DAVID LIN, SENIOR DIRECTOR FOR FUTURE TECHNOLOGY PLATFORMS, SPECIAL COMPETITIVE STUDIES PROJECT

COMMISSIONER KUIKEN: Thank you, Ms. Dohmen.

Mr. Lin.

MR. LIN: Good morning, members of the Commission. Thank you for the opportunity to be here, and I am honored to be a part of the panel with my fellow panelists. My name is David Lin. I am the Senior Director for Future Technology Platforms at the Special Competitive Studies Project.

I had a front-row seat to the early days of Made in China 2025 during my time as an economic officer working at the U.S. Consulate in Shanghai. When I arrived just months after the initiative's launch I could feel the energy among local party leaders and industry executives. To them, this wasn't just an economic policy. It was an industrial reawakening, a chance for China to climb the value chain.

A phrase I often heard at the time captured this ambition. China no longer wanted to be just the place where foreign products are designed and assembled. No more "Designed in California, Made in China" stamped on the back of the iPhone. Instead, they envisioned a future where the same devices would read, "Designed in China, Made in China."

At the time, the idea of China producing a technology on par with the iPhone seemed very far-fetched. Yet fast forward a decade, here we are. Companies like Huawei, ZTE, Xiaomi are not just competing but they are shaping the global tech industry and beyond. This trajectory is more than just a success story and underscores a broader reality. China isn't merely catching up; it is positioning itself to lead.

My testimony today is based on some of the work that we have been doing at SCSP and will focus on three areas: (1) tech areas where China leads today; (2) tech areas where China intends to lead tomorrow; and (3) I will conclude with some remarks with some high-level recommendations on what the United States should do to maintain its technological leadership.

Examining areas where China leads today. Nearly a decade into Made in China 2025, clear patterns have emerged. China's greatest advantages align with its greatest strengths, leveraging its vast manufacturing base and scaling technological development at an extraordinary pace. In SCSP's recently published 2025 Gaps Report, we identify 12 technology areas to zoom in on and examine as a barometer of the state of the competition.

China's industrial prowess really comes through in our analysis as the four technologies we judge that China is leading are all heavily infrastructure- and manufacturing-focused. Meanwhile, four of the five technologies we assessed the U.S. to be leading are either more software-based or not yet fully commercialized.

Tech sectors such as advanced batteries, 5G infrastructure, and commercial drones are all areas where we judge China to be holding commanding leads. China's DJI, for example, controls 90 percent of the global consumer market and 70 percent of the overall drone sector.

Advanced manufacturing, embodied in robotics and other manufacturing technologies is another area where we assess China to be holding key advantages. According to a 2024 U.N. study, by 2030, China is expected to claim 45 percent of global industrial production while the United States is expected to only hold 11 percent.

So that is a snapshot of where we are at today. Let's pivot to look at where China intends to lead tomorrow.

Looking ahead over the next decade, China will likely face significant economic and

demographic headwinds, including a slowing GDP growth rate and aging population, all of these factors exacerbated by increasing geopolitical tensions. That said, Beijing sees technology and innovation as its key solution to solving all of these challenges.

Two more future-oriented technologies that will be central to the next decade of competition are (1) AI and artificial general intelligence, and (2) perhaps a less widely talked about technology but by our judgment equally important and strategically important is fusion energy.

First, artificial intelligence. In our Gaps Report we assess AI to be squarely in the contested space, and it will likely continue to be prominently featured in future Chinese industrial plans and technology development plans. The recent unveiling of DeepSeek's R1 model underscores China's rapid progress in this space.

For fusion energy, while the U.S. currently leads in fusion research, China is investing heavily to close the gap. Fusion offers the potential for an abundant, clean, and geographically independent energy source which carries with it a whole slew of downstream economic and geopolitical implications. As if making fusion science breakthroughs is not challenging enough, building a first-of-a-kind fusion machine is very complicated and leans towards China's infrastructure-first advantages.

In terms of opportunities for U.S. action, to maintain leadership, the United States must adopt a two-pronged strategy -- countering China's advances while accelerating domestic innovation. I would like to put forth two high-level recommendations along these lines.

First, is the need for a structured framework that establishes clear criteria and baselines for how to prioritize technologies we deem central to the competition and core to U.S. national security interests. Not all technologies pose the same risks. Not all technologies have the same strategic or commercial value. SCSP has put forth one such framework to navigate these questions and bring to the fore the tradeoffs that we must make, and I have included them with my written testimony.

Second is the need for a policy roadmap to build future technologies. The U.S. must bridge the gap between research and large-scale deployment, and some of the ways we propose to do that include investing in AI-powered research tools to accelerate scientific discovery, boost support for deep tech and digital infrastructure projects, establish regional innovation zones to push development and adoption of emerging technologies, and other recommendations, which I am happy to go into more.

In conclusion, reflecting on my time on the ground in China I remember initially carrying certain assumptions, chief among them that a heavily censored, top-down, party-led system would struggle to innovate. Yet I quickly learned and saw firsthand how such a system can be surprisingly agile, resilient, innovative in ways that defy conventional wisdom. In any competition, underestimation is a mistake. A serious competitor must analyze with both clear-eyed scrutiny, and at times, grudging admiration. Understanding of the strengths and weaknesses in depth is essential to developing a winning strategy.

So if anything is clearer 10 years after the introduction of Made in China 2025 it is that technological leadership is not just about who invents the future but who builds it.

Thank you again for the opportunity to testify, and I look forward to your questions.

PREPARED STATEMENT OF DAVID LIN, SENIOR DIRECTOR FOR FUTURE TECHNOLOGY PLATFORMS, SPECIAL COMPETITIVE STUDIES PROJECT

Testimony Before the U.S.-China Economic and Security Review Commission

February 6, 2025

"Made in China 2025—Who is Winning?"
Panel II: The Next Decade of U.S.-China Tech Competition

Prepared statement by
David Lin, Senior Director for Future Technology Platforms
Special Competitive Studies Project (SCSP)

I. Introduction

Members of the U.S.-China Economic and Security Review Commission, it's an honor to be invited here today to share my perspectives on the next decade of the U.S.-China tech competition. My name is David Lin. I am Senior Director for Future Technology Platforms at Special Competitive Studies Project (SCSP), a nonpartisan, nonprofit making recommendations to strengthen U.S. competitiveness as emerging technology is reshaping our economy, national security, and society. At SCSP, the Future Tech Platforms team is charged with scanning the horizon for emerging geopolitical and tech trends and developing policy recommendations for the United States to maintain positional advantage vis-à-vis our competitors.

My testimony today draws from the work we have been doing at the SCSP and will provide our assessments on which technology areas China leads today, which sectors China intends to lead in tomorrow, and offer some recommendations on how the United States should position itself going forward into the next decade.

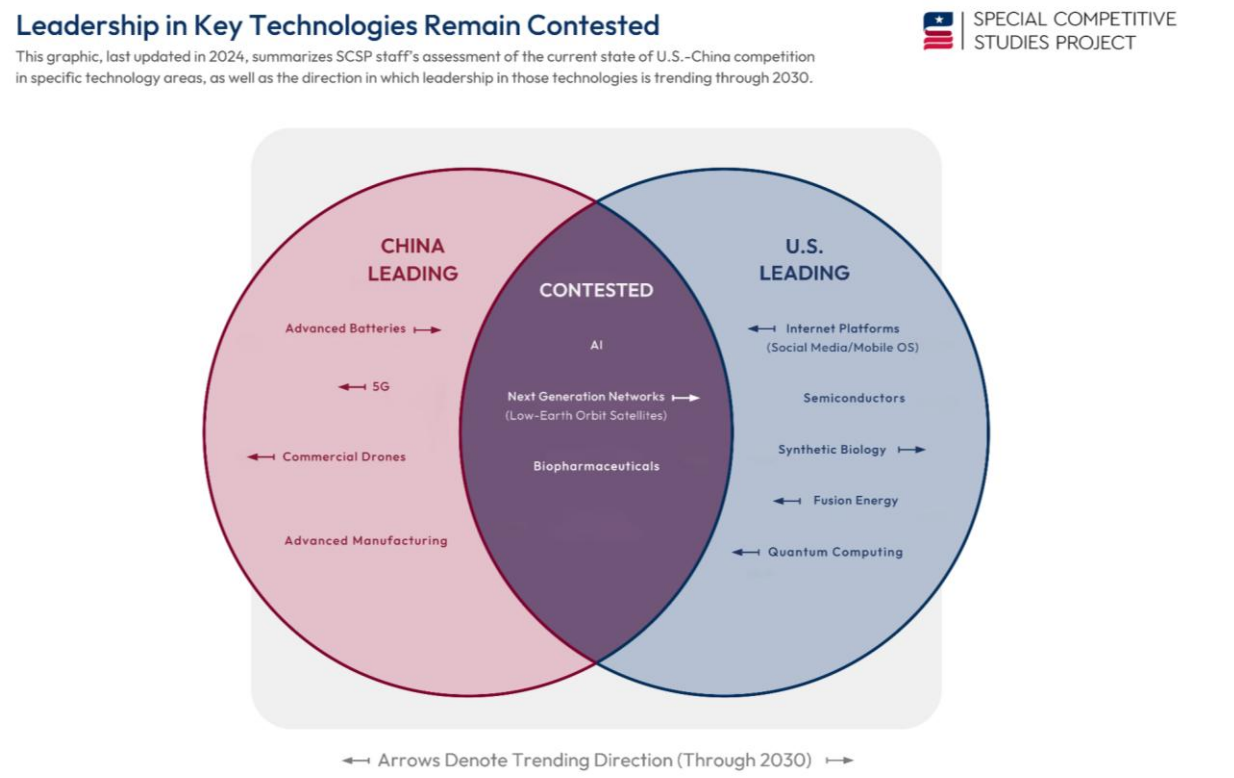
I got to witness the early years of Made in China 2025 firsthand when I was posted there as an economic officer in the U.S. Consulate Shanghai. I had landed in China just months after the initial rollout of Made in China 2025 and recall attending several local industry conferences and seeing the excitement surrounding the industrial plan. Local Party leaders and industry executives looked at Made in China 2025 as an industrial reawakening. A common refrain at the time was that China's aspiration was to move up the value chain—to ultimately change the Apple iPhone tagline from "Designed in California, Made in China," to "Designed in China, Made in China." I remember at the time how inconceivable it was to many that China would ever be able to manufacture a piece of technology that could match the caliber of an Apple iPhone. But fast forward ten years, and here we are—numerous homegrown Chinese companies – Huawei, ZTE, Oppo, Vivo, Xiaomi—are producing leading-edge smartphones and becoming serious global competitors. And this is just the beginning of the story.

II. Where China Leads Today

In 2015, Beijing laid out its ambitious state-led plan to transform the country into a global manufacturing and technological powerhouse, targeting ten strategic sectors from robotics to next-

generation information technology to electric vehicles.[1] Nearly a decade into this initiative, a clear pattern has emerged: China's greatest advances and closest approaches to global leadership are in sectors that leverage the country's sprawling manufacturing industrial base.[2] China's infrastructure-first approach to technological development has yielded formidable industrial advantages in scaling and implementing technologies, exemplified by its high-speed rail systems and renewable energy development. China's manufacturing prowess has enabled it to move beyond imitation to iteration; by co-locating manufacturing facilities with R&D hubs, China has been able to rapidly experiment and deploy new innovations.[3]

At SCSP, we identified six battleground sectors that we judge to be central to the U.S.-China technology competition—advanced manufacturing, biotechnology, advanced compute and microelectronics, next-generation energy, advanced networks, and artificial intelligence (AI). Within these sectors, we down-selected twelve key technologies to assess where China is ahead, where the United States is ahead, and where the technology competition is headed next.[4]



Focusing on the four technologies that are in the red sphere, where we assess China to be leading, we see China's industrial manufacturing advantages shine through. All four of these technologies

[1] An Initiative So Feared that China has Stopped Saying its Name, The Economist (2025).

[2] Harold Thibault, Ten Years On, The Relative Success of Beijing's Made in China 2025 Plan, Le Monde (2025); Joe Weisenthal & Tracy Alloway, Almost 10 Years Later, China's 'Made In 2025' Has Succeeded, Bloomberg (2024).

[3] Dan Wang, "China's Hidden Tech Revolution," Foreign Affairs (2023).

[4] Welcome to the Arena: Who's Ahead, Who's Behind, and Where We Are Headed Next in the U.S.-China Technology Competition, Special Competitive Studies Project (2025).

are infrastructure and manufacturing-intensive. Beijing has demonstrated particular strength in commercializing and deploying advanced batteries, 5G infrastructure, commercial drones, and, of course, advanced manufacturing.

In **advanced batteries**, China's strategic focus on refining critical minerals like lithium and graphite has enabled it to control 80% of the world's lithium-ion battery component shipments in 2023, while simultaneously developing an unparalleled battery manufacturing capacity of 1,705 gigawatt-hours (GWh).[5] As a result, China maintains its global market leadership through this low-cost battery production dominance. Yet, recent U.S. investments through the Inflation Reduction Act have begun to narrow this gap by spurring our own manufacturing capabilities. The sector is now trending toward becoming contested rather than China-dominated.

In **5G infrastructure**, China has significantly strengthened its lead over the past three years, deploying low-cost networks at scale. With 4 million base stations deployed domestically, over 1 billion 5G connections, and coverage for 88% of its mobile users, China has achieved a broader, denser, and more affordable 5G network compared to the United States.[6] Globally, China is also working to enmesh itself in 5G networks through its Digital Silk Road initiative.[7] Years of policy gridlock and slow progress on Open RAN development have allowed China's advantage to grow even further, but recent Congressional movement on spectrum policy and federal funding for removing Chinese infrastructure are positive signs that U.S. competitiveness in this tech area may be getting back on track.

The **commercial drone** sector remains firmly under Chinese control as DJI holds 90% of the global consumer market and nearly 70% of the drone sector writ-large.[8] In the United States alone, DJI controls 80% of the commercial market.[9] Chinese drones consistently outperform competitors in reliability, cost-effectiveness, and operational stability. While the United States has seen some promising drone startups emerge, China's leadership position remains secure.

Perhaps most significantly, China has established a clear lead in **advanced manufacturing**. As the Made in China 2025 strategy set out to do a decade ago, China now leads the world in manufacturing capacity and, in 2023, deployed as many industrial robots as the rest of the world combined, positioning the country to capitalize on advanced manufacturing trends.[10] China's

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[5] China's Market Share in Key EV Battery Components Tops 80%, Nikkei Asia (2024); Leading Countries by Battery Manufacturing Capacity Worldwide in 2023, Statista (2023).

[6] Juan Pedro Tomas, China Reaches Over 4 million 5G Base Stations, RCR Wireless (2024); Number of 5G Base Stations in Selected Countries Worldwide 2023, Statista (2024); The 5G Marathon, KPMG UK (2024); China's 5G 'Subs' Climb to 1.15 billion, Telecom TV (2024); Catherine Sbeglia Nin, China to surpass 1 billion 5G Connections this year, RCR Wireless (2024); Dan Strumpf, U.S. vs. China in 5G: The Battle Isn't Even Close, Wall Street Journal (2020).

[7] Mid-Decade Challenges to National Competitiveness, Special Competitive Studies Project (2022).

[8] Zeyi Yang, Why China's Dominance in Commercial Drones Has Become a Global Security Matter, MIT Technology Review (2024); Ishveena Singh, The Secret to DJI's Drone Market Dominance: Revealed, DroneDJ (2024).

[9] Brad Dress, China's Dominant Drone Industry Is a Step Ahead of Congress, The Hill (2024).

[10] Richard Baldwin, China is the World's Sole Manufacturing Superpower: A Line Sketch of the Rise, Centre for Economic Policy Research (2024); Record of 4 Million Robots in Factories Worldwide, International Federation for Robotics (2024).

ability to rapidly adopt, scale, and deploy new manufacturing techniques throughout its domestic supply chain, has allowed it to set global standards in this space.[11]

III. Where China Seeks to Lead Tomorrow

China will be facing major headwinds as it looks toward the next decade of technological and industrial development. China's era of double-digit economic growth is over: GDP growth will likely slow to 4.5% this year and to 4.2% in 2026, though some economists speculate the growth will be even lower.[12] At the same time, China faces demographic challenges as its population fell once again for the third year in a row.[13] This is all occurring as geopolitical tensions with the United States are poised to continue to escalate, especially with proposed trade restrictions and export controls.[14] For all three challenges, Beijing views technology and innovation as being central to the response.

Nevertheless, China continues to strive for dominance in these critical tech domains. This is demonstrated through two case studies: first, artificial intelligence, which received widespread attention last week with the entrance of DeepSeek, and second, perhaps a less well-covered emerging technology, fusion energy, something that has not yet been commercialized, but a sector expected to experience big movements in the next five to ten years.

Artificial Intelligence. AI is a convergence of a multitude of factors, from algorithms to data centers, leaning on a nation's hardware and software capabilities.[15] AI is one of China's highest-priority sectors, featuring prominently in several of Beijing's high-level industrial plans and strategies, including its 14th Five-Year Plan published in 2021,[16] and, of course, Beijing's 2017 New Generation AI Development Plan.[17] AI is expected to feature prominently in the upcoming 15th Five-Year Plan, which we should be seeing a preview of later this year. In SCSP's Gaps analysis report, we make clear AI is a hotly contested area.

According to the PRC's 2017 AI Development Plan, by 2025, Beijing sets the goal of *"[achieving] major breakthroughs in basic theories for AI, such that some technologies and applications*

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[11] Robert D. Atkinson, China Is Rapidly Becoming a Leading Innovator in Advanced Industries, Information Technology & Innovation Foundation (2024); Gerard DiPippo, et al.,Red Ink:Estimating Chinese Industrial Policy Spending in Comparative Perspective, Center for Strategic and International Studies (2022).

[12] Kevin Yao, China's Growth Seen Slowing to 4.5% in 2025 as US Tariffs Bite, Reuters (2025); Claus Soong & Andreas Mischer, MERICS China Forecast 2025: Economic Stress Increases Risk of Domestic Instability, MERICS (2025).

[13] Christopher Bodeen, China's Population Falls for a Third Straight Year, Posing Challenges for its Government and Economy, Associated Press (2025); Lizzi C. Lee, Xi Jinping Doesn't Have an Answer for China's Demographic Crisis, Foreign Policy (2024).

[14] China 2025: What to Watch, Asia Society Policy Institute (2024); MERICS China Essentials Special Issue: China in 2025, MERICS (2024).

[15] Paul Triolo & Kendra Schaefer, China's Generative AI Ecosystem in 2024: Rising Investment and Expectations, The National Bureau of Asian Research (2024).

[16] 中华人民共和国国民经济和社会发展第十四个五年规划和2035年远景目标纲要 (Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Term Objectives for 2035), Xinhua News Agency (2021).

[17] 新一代人工智能发展规划 (New Generation Artificial Intelligence Development Plan), State Council (2017).

achieve a world-leading level and AI becomes the main driving force for China's industrial upgrading and economic transformation, while intelligent social construction has made positive progress." By 2030, China aims to be "*the world's primary AI innovation center.*" You can argue that with DeepSeek's R-1 model unveiled just a few weeks ago, China may well have taken one big step toward reaching its 2025 goal. There are still many questions we don't know the answer to yet surrounding DeepSeek and its latest model, but one thing that the PRC firm has demonstrated is how improving and combining AI functions can lead to breakthrough performance at lower computing cost and also form a pathway toward artificial general intelligence (AGI).[18] In fact, DeepSeek's company tagline references AGI as an implicit goal: "DeepSeek, unravel the mystery of AGI with curiosity. Answer the essential question with long-termism."[19]

China has at least two national programs with the open ambition to achieve AGI. Beijing Academy of Artificial Intelligence (BAAI) focuses on fundamental research and talent cultivation, aiming to achieve breakthroughs in core AGI technologies.[20] Beijing Institute for General Artificial Intelligence (BIGAI) is dedicated to building safe and controllable AGI systems, with a strong emphasis on cognitive science and neuroscience.[21] DeepSeek's emergence, however, is an interesting contrast to what is typically described as a government-centric, heavy-handed approach to innovation in China. The company's relative obscurity, combined with its lack of a direct government connection and even a lack of a direct commercial tie to China's big AI developers like Alibaba, Tencent, and Baidu, puts a spotlight on the role of a small group of moderately-funded Chinese engineers can play in China's innovation ecosystem and how Beijing is turning to open-source as a pathway to technological advancement. Indeed, this may be a new path for Beijing to reach its stated AI goal that by 2030, *"China will achieve major breakthroughs in basic theories for AI, such that some technologies and applications achieve a world-leading level and AI becomes the main driving force for China's industrial upgrading and economic transformation, while intelligent social construction has made positive progress."*

Fusion Energy. China is also rapidly closing the gap with the United States in fusion. While the United States currently leads in fusion energy—exemplified by the Lawrence Livermore National Laboratory's (LLNL) fusion breakthrough in 2022—the race to build the first commercial fusion machine highlights America's challenges with first-of-a-kind infrastructure deployment.

While China's strategic approach deliberately mirrors U.S. development plans, China is investing nearly double the U.S. Department of Energy's fusion budget.[22] The nation also produces ten times as many fusion science Ph.D.s as the United States, and surpassed American patent applications in fusion technology two years ago.[23] China is translating this research and funding into tangible results, constructing a complete development pipeline. Facilities that are underway, like the Experimental Advanced Superconducting Tokamak (EAST), the Burning Experimental

[18] Urgent Memo to the President on DeepSeek's Arrival, Special Competitive Studies Project (2025).
[19] DeepSeek Homepage, DeepSeek (last accessed 2025).
[20] About BAAI, Beijing Academy of Artificial Intelligence (last accessed 2025).
[21] Beijing Institute for General Artificial Intelligence (last accessed 2025).
[22] Jean Paul Allain, Building Bridges: A Bold Vision for the DOE Fusion Energy Sciences, Office of Science for Fusion Energy Sciences (2023).
[23] Jennifer Hiller & Sha Hua, China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail, Wall Street Journal (2024); Rimi Inomata, China Tops Nuclear Fusion Patent Ranking, Beating U.S., Nikkei Asia (2023).

Superconducting Tokamak (BEST), and the China Fusion Engineering Test Reactor (CFETR), all build upon each other towards a functioning, gigawatt-scale fusion power plant by the 2050s.[24]

China is also actively securing dominance in the fusion supply chain and leveraging its already tight control over critical minerals and manufacturing to scale fusion energy. This mirrors its success in other energy technologies, like solar PVs or electric vehicle batteries, and raises concerns that the United States may be the first to invent but struggle to scale its fusion breakthroughs into commercial reactors. These concerns are amplified as China already has a robust nuclear industry overall. With 22 of 58 global nuclear fission reactors under development, China has a significant infrastructure advantage.[25] In contrast, the U.S. regulatory hurdles have delayed conventional nuclear expansion, which could impact how quickly the nation can transition from demonstration to deployment of fusion power.

At the current pace, experts predict China could overtake U.S. and European magnetic fusion capabilities within three to four years.[26] While American leadership in foundational research and private investment remains strong, the path to commercial fusion requires bridging the gap between laboratory success and scalable power plants—precisely the kind of infrastructure challenge where China's comprehensive, state-backed approach could prove decisive.

IV. Opportunities for U.S. Action: Protect and Promote

For the United States to lead in critical technology, it will be paramount to deploy a two-pronged approach where we protect our nation by developing policy measures designed to counter and slow our adversaries, all while we promote our technology through policy measures designed to build domestic capacity and accelerate homegrown innovation. To achieve these goals, I would like to share two recommendations: 1) the **United States must develop a clear framework to better prioritize the way we address technology threats** posed by our competitors, and 2) the **United States requires a roadmap to win the future technology transition**.

First, why do we need a better framework to guide how we prioritize protecting ourselves from foreign technology threats? In the era of technology competition, we must operate in a reality that:

1. Virtually all technology is dual-use, with both military and civilian applications;
2. Anything connected to the Internet is hackable and exploitable; and
3. Virtually every supply chain for technology commodities today has a link to China.

In light of that, we have recently seen in the headlines a wide spectrum of technologies that could pose a threat to both national interests and to the individual American consumer, ranging from commodity electronics like PRC-origin mesh routers and OLED panels to software and mobile applications to industrial-scale infrastructure, like smart cranes and interconnected vehicles. There are technical explanations for how China could exploit these technologies. There are also technical measures that could be adopted to mitigate those threats. The current ad-hoc, patchwork of policy

[24] Welcome to the Arena: Who's Ahead, Who's Behind, and Where We Are Headed Next in the U.S.-China Technology Competition, Special Competitive Studies Project (2025).
[25] Sha Hua, Atomic Power Is In Again—and China Has the Edge, Wall Street Journal (2023).
[26] Jennifer Hiller & Sha Hua, China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail, Wall Street Journal (2024).

solutions to addressing these very different technologies could, in fact, unintentionally undermine public safety and, ultimately, national security. Hovering above the fray is the need for clear criteria, first principles, or a framework to help policymakers, business executives, or even everyday Americans assess risk so that we don't inadvertently undermine U.S. industry, hinder American innovation, and ultimately, leave the nation disadvantaged in the tech competition with China.

To help policymakers sort through the signal from the noise, SCSP developed a strategic evaluation framework consisting of a set of strategic questions for policymakers. This framework offers policymakers a structured evaluation of how to determine which technologies require whole-of-nation attention through three lenses: a technological lens, a rival ecosystem lens, and through the lens of our domestic ecosystem.[27] This framework brings to the surface several key considerations that policymakers should be asking themselves when prioritizing foreign technology threats, such as:

1. How close is this technology to market adoption? What is the technology's tech readiness level (TRL)? What is its timescale for deployment?
2. How big of a technological chokepoint is the technology? Are there non-China alternatives? How commoditized is the technology?
3. Is the technology more geopolitically strategic or more commercially valuable to the United States? Does it shape entire critical industries, like semiconductor fabs, or is it more consumer-facing, like the video games industry?

The current ad-hoc policies addressing foreign technology threats risk inefficiencies and unintended consequences, making the need for a clear, structured framework more urgent than ever. The SCSP's strategic evaluation framework offers a methodical approach for policymakers to assess technological threats through the lenses of technology readiness, China's influence, and U.S. strategic interests. By prioritizing threats based on these criteria, the United States can better mitigate risks without stifling its own technological advancements. Ultimately, a proactive, well-defined roadmap will be essential to maintaining U.S. leadership in critical technologies and securing the nation's competitive edge in the decades to come.

My second point is more domestically focused, and that is how the United States must confront a broader obstacle of bridging the gap between technological innovation and deployment. Beijing's ability to turn strategy into action poses a threat to America's technological leadership. Should China gain the upper hand, an authoritative state would control the world's digital infrastructure, dominate the world's technology platforms, and command the means of production for critical technologies. Most importantly, China would be positioned to harness emerging general-purpose technologies to transform its society, economy, and military, potentially securing innovation power—the ability to invent, adopt, and adapt new technologies—for generations to come.[28]

[27] Platforms Interim Panel Report, Special Competitive Studies Project (2022).

[28] Mid-Decade Challenges to National Competitiveness, Special Competitive Studies Project (2022); Innovation Power for the Generative AI Flywheel, Special Competitive Studies Project (2023).

SPECIAL COMPETITIVE STUDIES PROJECT

Strategic Evaluation Framework

These questions can be used to find strategic signal in the noise to define national technology goals to enhance American competitiveness in the 2025-2030 timeframe.

Technology Factors

Is this technology strategically important enough to warrant fostering a dominant national position?

- Could this technology yield a revolutionary breakthrough that upends existing paradigms or fundamentally changes the way the world works?
- Is this a general purpose technology (GPT) like electricity that could subtend or accelerate many other sectors?
- Does this technology present or solve a novel, foreseeable, and material existential national security threat?
- Could this technology alter the economic fundamentals of the United States? Relatedly, does this technology or program present massive spinoff potential?
- Could this technology change the military balance of power outright by its existence?
- Could this technology transform the means of production of information and/or the control of its flow in society?
- Does this technology possess "first-mover" criteria such as scarce factors of production, network effects, or other forms of potential lock-in.

Rival Factors

Are U.S. rivals positioned for strategic advantage in this technology?

- Are rivals ahead in this area? Is there a need for an offset/leapfrog move due to blindspots of U.S. commercial investment?
- Are rivals substantially trying to get ahead (strategy, invested, determined, aligned public and private efforts towards its development)?
- Are rivals likely to get ahead due to technology readiness level in their ecosystems compared with the U.S. ecosystem?
- Do rival economic/political systems obviously favor development of this technology over others (e.g. resource allocation, regulatory environment, norms)?
- Does this technology represent a major or potential front along clashing tech-spheres of influence?
- How will U.S. rivals react to U.S. development of or leadership in this technology? Does this technology intersect with weaknesses, organizational inertias, or fundamental asymmetries of U.S. rivals?
- Can we foresee how future rival leadership in this space could fundamentally undercut U.S. leadership and power?

Domestic Factors

What needs to be done to ensure a strong U.S. position?

- Is the U.S. innovation ecosystem naturally generating sufficient advantage?
- Is there a clear U.S. competitive advantage surrounding this technology that needs a national endeavor to harvest?
- What is the maturity level of this technology? Would the U.S. need to "invent the future" to achieve positional advantage?
- Has the U.S. government listed this technology as a priority threat or opportunity area? What is the level of political or social will for this technology?
- Do allies and partners currently possess the key expertise and materials/resources in this technology?
- How might other countries respond to a U.S. national endeavor and are there obvious opportunities for joint efforts with allies?
- Which factors (incentives, financial, political, organizational, or regulatory) are currently limiting progress on this technology in the U.S.? Are these in the USG's control?

In light of these stakes, the United States currently faces five key obstacles to winning the tech competition. First, the federal government is often too focused on firefighting today's crises rather than strategic planning and investment in future technologies. Second, as previously mentioned, while the United States often pioneers groundbreaking technologies, China frequently stays ahead by rapidly adopting, refining, and scaling these innovations. Third, we are underinvesting in technology infrastructure. Fourth, bureaucratic hurdles are hindering the development and commercialization of potentially groundbreaking technologies. Finally, persistent security shortfalls leave critical systems vulnerable to exploitation and cyber attacks.[29]

To overcome these obstacles, America must **organize, innovate, build, deploy, and secure** the technology stack of the future. In SCSP's recent Memo to the President on the Future Technology Transition, we lay out five steps on how to do this.[30] First, the United States needs to **organize** and establish a White House Technology Competitiveness Council that can horizon scan and coordinate our national technology strategy. Second, we must **innovate** and increase funding for AI-powered research tools, like self-driving labs, that will accelerate discovery and enable scientific breakthroughs. Third, we have to **build** and break ground on critical technology infrastructure, such as next-generation energy systems, that form the foundation of emerging technologies. To execute these priorities effectively, the federal government should enable the **deployment** of technologies through the creation of regional innovation zones across the nation to empower localities to become "first movers" in critical technology areas, because innovation truly occurs at the local level.

Finally, we must **secure** American innovations, from development to deployment, to protect research, critical infrastructure, our supply chains, and even intellectual property because, ultimately, success in this technological competition with China requires a combination of both protection and promotion. We must simultaneously strengthen and accelerate our domestic innovation ecosystem while implementing targeted measures to hinder China from achieving dominance in critical sectors. This comprehensive approach that pairs strategy with action will be essential for maintaining American technological leadership today and tomorrow.

V. Conclusion

Overall, ten years after the launch of Made in China 2025, we see that China's success stems not from innovation alone but from its systematic ability to scale and deploy technologies across its vast industrial base. Even in areas where the United States maintains leadership—from fundamental AI research to fusion science—China's infrastructure-first approach and coordination between state and industry threatens to close these gaps faster than many expect.

The United States cannot afford to be complacent, even in areas where it currently leads. Today's edge in technologies like quantum or biotechnology could follow the same pattern as solar panels and drones without a more comprehensive approach to maintaining leadership. Success in this competition demands a proactive strategy that accelerates the transition from innovation to industrial-scale deployment, builds robust manufacturing capabilities, and creates regulatory

[29] Memos to the President: Future Tech Transition, Special Competitive Studies Project (2025).
[30] Memos to the President: Future Tech Transition, Special Competitive Studies Project (2025).

frameworks that enable rapid scaling while protecting security interests. The lesson from nearly a decade of Made in China 2025 is clear: technological leadership is not just about who invents the future, but who builds it.

Thanks to Nyah Stewart, Libby Lange, and Channing Lee for their assistance in preparing for this hearing.

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PANEL II QUESTION AND ANSWER

COMMISSIONER KUIKEN: Thank you to each of you for your testimony. I am going to turn it over to Commissioner Schriver for the first questions.

VICE CHAIR SCHRIVER: Thank you. Let me start with Mr. Khang. Thank you for your testimony. You mentioned that your written testimony includes recommendations, which indeed they do, and I think they are quite good. You didn't speak to it too much in your opening statement, so I want to give you that opportunity. And I really note your phrase, that we have no counter-talent acquisition strategy, and no counter-talent acquisition policies.

So the sum of your recommendations, I think, sort of amount to that, but could you talk about what the priorities should be in building a counter-talent acquisition strategy?

MR. KHANG: Thank you, Commissioner. So there is an institute called the Chinese Academy of Personnel Sciences in China. Ms. Dohmen just talked about Chinese Academy of Sciences but that is more famous. This one is more obscure. It is basically the national center for the development of talent policies, study of the art and science of talent attraction, and evaluation of the current ongoing policies.

This center was integral in inventing the Thousand Talents plan. They have also reoriented China's system for talent attraction to fit with MIC 2025, and they have lowered many of the barriers for moving from the U.S. or foreign countries to China. These are the strategies that they espouse and they developed.

We need something like that. One of my recommendations is why don't we have a national talent research center? We have nothing analogous to that in this country. Are we not taking this seriously? Talent is something that we can study to attract. Our natural attractiveness, this country's freedoms, is already very, very good. It attracts people naturally. Our university systems are the best in the world. But we can't just rely on that. We need to study the art of it. The best defense might be an offense, and I think this is one of the first steps that we can take to address this.

Second might be a little bit more critical of our current system, but there is no congressional legislation of requiring the transparency requirements for universities and research labs in this country to disclose any research with PRC military R&D organizations. Some of the publications that I have seen, they talk about drones, they talk about targeting technologies, hypersonics, they talk about silent submarines. This is research being done by universities in this country with PRC military academies and research institutes in China, as of like last year.

So this continues on, and there is no law, other than, you know, we did have the Presidential National Security Memorandum 33, but I don't think it has enough teeth. So I think we need to have a congressional legislation around this.

And I did talk about some of these Chinese HR companies raising money in this country to then help the CCP siphon off talent into China. We need to stop that. We should not allow these companies that belong to the United Front system and registered as such to raise capital in our stock markets.

And lastly, we need to do a little bit of a review of our 501(c)(3) nonprofit system. If the majority of your income comes from the government of an adversarial nation, that is not really the spirit of that tax code that we built into it. They are taking advantage of that, and they are not paying taxes, and taking the money from the PRC government to siphon off talent into the PRC. We need a review of some of those organizations.

So those are some of my top-line recommendations.

VICE CHAIR SCHRIVER: Thank you. Ms. de La Bruyère, you offered some policy recommendations, some of which were directed at partners and allies, and it sounded to me like potentially tough medicine. If they don't play ball on export controls then they should lose access to our markets, which I assume means tariffs or something.

Is it going to be that hard? Do you anticipate that we will have difficulty bringing allies along? Will we need to resort to such measures? That seems like inviting trade wars, more broadly, and maybe it is that important and that critical. But just your thoughts on that.

MS. DE LA BRUYÈRE: We have clearly made an effort to bring our allies along in our competition with China, and up to this point we have failed in that effort. America has an enormous network of allies and partners. China has no allies. And yet in the competition right now that has been a disadvantage for us because our allies have provided conduits for China to access our market and to access our technology.

So yes, we do need to play hardball. Will that be difficult? It depends when we do that. Right now we have major negotiating power. We have the world's largest market. The longer we wait, the more we lose that power.

I do think that our allies have recognized, as we have, that removing China from the international trade system is in all of our long-term interests, and I do think that changes the state of play in terms of bringing them on board. But nobody, not our allies, not our companies, want to deal with the short-term cost of what it would mean to take the kind of action we do have to take in the immediate if we are going to win in the long-term. So that means that there also have to be short-term penalties for not being on board.

VICE CHAIR SCHRIVER: Thank you. If there is a second round I might have some follow-up.

COMMISSIONER KUIKEN: Thank you, Commissioner Schriver.

Mr. Lin, SCSP has done a lot of work on the issue of artificial general intelligence. As you probably know, this Commission's top recommendation last year was to create a Manhattan Project-like sprint on AGI. I want to just get your sort of more drawn-out views on this topic and how you have thought about this, what actions you think the United States government should do.

And then if you don't mind, you touched briefly, and so did Ms. Dohmen, on sort of DeepSeek. In the context of thinking about and evaluating a sprint to AGI, seeing what DeepSeek was able to do with sort of limited resources, limited compute, how should we think about a Manhattan Project-like approach on AGI?

MR. LIN: Sure. Thank you, Commissioner Kuiken, for that question. To segue to DeepSeek also, just to put on the record, DeepSeek's stated company mission is to work toward AGI, which is a testament, again, to China's AI ambitions. And I think really this is a matter about competition toward being a first mover advantage. The first person AGI will bring with it, whole downstream effect of economic, political, energy, supply chain influence around the world.

And it is also a competition of our norms. The Chinese Communist Party has a certain vision of the role of the Party's ideology and the way the global economy and global technology is operated and developed. And I think as the United States, being champions of the democratic values that we stand behind, are incredibly important, especially in the face of this potentially world-changing technology of AGI.

So I will just leave that there.

MS. DOHMEN: Yeah, maybe a couple of other additional comments to that. David

mentioned first mover advantage. There is certainly an advantage to being the first mover, and you are right, DeepSeek, it is part of their mission to move towards AGI.

I think it is also worth thinking about what it means to be a first adopter, first mover advantage and first adopter advantage. I would point, in particular, to Dr. Jeffrey Ding's work at GW who has written a book about this, that it also matters not just who gets there first but also who adopts it and diffuses the technology through the economy the most efficiently and the best. That is going to be how we reap the productivity benefits from a technology, diffusing it into our economy.

Just a point quickly about AGI and the path that the U.S. is taking right now. I think there is a lot of discussion still about what the right path to AGI is. I think we have put a lot of focus on large language models, and we are not saying that is wrong. I think the push forward in that direction is the right one. But I think it is also worth considering alternative paths, because there is a lot of uncertainty. We just don't know at this point in time. And I would point to some of colleagues' work specifically looking at how China is approaching AGI. Bill Hannas and Huey-Meei Chang at CSET have written extensively about this, and they have found that China is taking kind of a more diversified portfolio of approaches to AGI. So it is not just focused on large language models but also alternative paths. So I would just encourage the U.S. to think about that, as well.

COMMISSIONER KUIKEN: Ms. Dohmen, you can't leave me with alternative paths without giving me a little bit more there. Just explain how you think the Chinese are thinking about this. Just build that out a little bit for me.

MS. DOHMEN: Sure. I think part of it is that there is a lot of uncertainty about whether LLMs will be able to -- there are a lot of weaknesses in how large language models work right now and a lot of challenges, like hallucinations and things like that. And there are some questions if we would be able to overcome those with further technological advancement.

I am not sure what the answer is. I would defer more to the technical experts on that. But there are also considerations to look further into like brain-computer interface, and China is doing a lot of research into that area. And I am happy to put you in touch also with some of our, Bill and Huey-Meei, who have been focused a little bit more on China's AGI paths, and I can send you the report that they published on this, as well.

COMMISSIONER KUIKEN: Thank you very much.

Mr. Lin, I am going to go back to you on AGI. As we talked about AGI as a Commission last year we made a fairly simple recommendation, basically to sort of say this is the strategic direction we want to go, and we need to make sure that the government is part of that conversation.

Has SCSP thought about, as you made sort of a similar push, how you operationalize something like this?

MR. LIN: Yeah. I would say we have put a lot of thought about government's role in building toward AGI. And similar to the recommendation that the Commission put forth last year, I think it really does come down to public-private partnerships. I don't think it is realistically, both from an investment or an operational perspective, to think that government alone can feasibly build the capabilities, the infrastructure, the energy demands necessary to build toward AGI alone. I think, as we have talked about today, a lot of the private capital has a huge role to play in AI, in the development, and the AI innovation aspects also.

So it has to really come down to, as the Commission has said, a Manhattan-style but public-private partnership to build towards this goal.

COMMISSIONER KUIKEN: Thank you. The clock says I am over time, and we are now going to do the reverse order that we did last time, which means our brand-new Commissioner, Commissioner Brands, is first up.

COMMISSIONER BRANDS: Thanks. Mr. Khang, could you maybe say a little bit more about your recommendation regarding research institutions? And you obviously favor stronger transparency requirements, and you lay out the failings of the system so far. Are we headed in the right direction even, or are we stuck in place on this? What does a stronger set of safeguards look like, and are there any positive examples we can look to of institutions that are doing this right?

MR. KHANG: Thank you, Commissioner. To answer your question directly, yeah, we are moving in a positive direction, and we see that at Strider. Many of our clients that are within the research institution system within the United States, and also abroad in our allied countries, and also universities, are waking up to especially PRC military research facilities.

So my recommendation here is not to, of course, bar collaborations of research with China writ large. That would be insane. But especially for that very small subset of organizations with direct ties to the PLA, for example, I don't think that we should allow universities to collaborate with these organizations with no transparency. So let's start there, with some transparency.

There are not that many organizations, probably less than 100 of these institutions in the PRC directly tied to the PLA. For example, Seven Sons universities, I am sure many of us in this room have heard of it. Seven Sons of National Defense and Seven Sons of Armaments, combined together, that is 12 universities.

PLA directly managed universities, there is really just one, NUDT, the National University of Defense Technology. That university directly manufactures weaponry for the PLA, and our national laboratories and universities are participating in research with this university. That has got to stop.

How about PLA military academies that train up PLA officers? We are conducting research together with these folks? I am not saying let's stop university collaborations with Beijing University, Tsinghua, Shanghai, Jiao Tong University, even though they are all managed by SASTIND, the defense agency in China. I am not even stretching it that far.

But there is a very small subset of very egregiously tied universities and institutes that work directly with the PLA. Let's start there with some transparency. I think that is where I would start.

COMMISSIONER BRANDS: One of the answers I think you might get from American academia on this is that it is sometimes hard to know exactly where the ties are between a certain person and the PLA, or a certain institute and the PLA. And we didn't know the guy was a senior colonel, or whatever the case may be.

So is that a plausible assertion on the part of universities and research institutions, and if it is plausible, what does that imply about the need perhaps for greater cooperation with the U.S. counterintelligence community so that those ties become a little bit more transparent on our side?

MR. KHANG: So that makes me scratch my head a little bit, because I found this information just in the open source. It is just out there. So if you are going to publish a research publication in an international journal, you need to disclose what organization you are affiliated with. To say that you didn't know that this person worked for NUDT or Harbin Institute of Technology, that doesn't make any sense to me.

The risk comes inherently from the organizations, and of course the people that work

within the organizations may be cogs in a wheel. Maybe they are not working for the PLA. However, we need to disclose that, have rules for disclosure, so that we can look at it clearly.

COMMISSIONER BRANDS: Let me ask it a different way, because I totally agree. There is one category where there is somebody or some institution that everybody understands is linked to the PLA, and if universities are not attentive, or research institutes are not attentive to that, that is a failure of due diligence on their part and a failure of transparency if they know it and do not disclose it.

Is there a second category where the links between a researcher or an institution and the Chinese government are less obvious, and if so, what do we need to put in place to guard against those types of linkages?

MR. KHANG: Yeah, I would say that is a difficult question and a difficult problem to solve because what we can't see, we can't see, right. And our intelligence agencies are not designed to give information to universities.

But at the same time, some of these obfuscation efforts can be taken apart. Let's say you have a researcher that works not with a university or a PLA institute but collaborates very often with them. That second layer networking, we can tease that apart, not only in open source but, of course, our intelligence community can help with that.

So I think there may be many different solutions to it, but putting some guardrails, at least setting some standards for disclosure I think would be a good start.

COMMISSIONER BRANDS: Thank you very much.

COMMISSIONER KUIKEN: Commissioner Friedberg.

COMMISSIONER FRIEDBERG: Thank you very much. Ms. de La Bruyère, good to see you. Thank you for your testimony. I wanted to start with you, if I could.

I want to make sure I understand what your final recommendation really is about. You talk about real system-level barriers, high and properly enforced tariffs, taking away China's Permanent Normal Relations status.

Is what you are suggesting essentially extruding China from the current international trading system and then allowing market forces to operate more freely within some more limited system of which we would be a central partner?

MS. DE LA BRUYÈRE: Yes. I am tempted to leave it there, but I will drone on a little bit. Free trade works if players are playing by the rules. I think there is a temptation, because we have a massive distortive actor like China in the system that is making it not work, to think that is a failure of the free trade system itself. It is not. It is a failure to defend its standards and to make sure that there is compliance across the board.

I also think that we, as the U.S., and also our allies, have tried to approach this problem with a scalpel, to say it is okay, we can deny China technology, or we can impose targeted tariffs on targeted goods, and that will level the playing field. But that doesn't work, based on either the way China competes or the resources we, as a system, like U.S. and our allies, have at our disposal. We are not players like China who can just go about and shift a couple of things and redefine markets. And because of that, we have to take a system-level approach, and that means precisely what you said, removing China from the system.

And I think it is fitting to be talking about this as a phenomenon in this particular room because of this Commission and when it was established and why. China's accession to the World Trade Organization was a high-risk move that I would argue has not panned out because China has not played by the rules. And the purpose of this Commission is to make sure that China does and to monitor the effects of that decision. And therefore, this seems like a right

place to think about the implications of changing the system China is undermining.

COMMISSIONER FRIEDBERG: Okay. Thank you. I am very sympathetic to this idea, at least in theory, but you know what all of the objections to a proposal like this would be. You know, it is going to drive up costs. We can't just do without China. Suddenly we are highly dependent on them for all kinds of intermediate goods, and so on.

Have you thought through it all, how you would respond to those kinds of objections?

MS. DE LA BRUYÈRE: I kind of thought that if I took long enough with my answer I would just get to leave it at that. But yes, it will drive up costs. It will create significant short-term harm for the U.S. consumer and for the U.S. producer. The problem is that there is not an alternative, and I think that is very clear in what we have seen over the past 4, 8, 10 years, because we have tried to not do that. And we have tried to say, okay, well, if we phase in measures, or institute them incrementally, we will build up the capacity we need to then either be able to take more severe action or not have to take it at all. And the problem is that has not worked because the U.S. system, which is to say markets, to really repeat myself a lot, does not answer to those moves because there is no resolve behind them.

And this is a very small case, but you can look at, for example, things like the rollback of bans on Chinese graphite in batteries that get IRA incentives. We said, okay, we can't do that right now because China makes all the world's graphite, so we said, okay, we will only put in that ban in two years, and that will build up domestic capacity such that we can ban it. But nothing happened in the market because that sent a message to the market that we weren't serious.

And so we still don't have domestic graphite capacity, so we still can't institute that kind of ban and then have domestic content in batteries. And we are just going to keep pushing the question and avoiding eating the costs and building up domestic capacity if we keep trying to take incremental measures.

COMMISSIONER FRIEDBERG: Okay. Thank you very much. I have just a few seconds. Mr. Khang, I wanted to ask you a quick question. The numbers of people who have been identified as recruited by the talent programs that you described, do you happen to know what portion of that total is Chinese nationals who are returning to China versus foreign nationals who are coming to China to work in laboratories or companies there?

MR. KHANG: So I don't have the top line numbers off the top of my head but I would say the majority of them are Chinese diaspora, located all across the world. But we do have a significant contingent of foreign nationals moving to China to work there.

COMMISSIONER FRIEDBERG: Okay. Thank you very much.

COMMISSIONER KUIKEN: First of all, Ms. de La Bruyère, great history on the United States Senate China Commission. I actually didn't realize the origin story was that Congress didn't trust the Chinese or the executive branch on PNTR, and that is why this Commission was created, so it was nice to hear it come back at me.

Commissioner Goodwin, over to you.

COMMISSIONER GOODWIN: Thank you, Mr. Chairman. Ms. de La Bruyère, I want to follow up on Commissioner Friedberg's question, actually, and maybe explore some different objections to some of your recommendations. I do like your turn of phrase about China playing a different game in the history with regard to their ascension to the WTO. Obviously, there were a lot of assumptions and hopes and aspirations built into them joining the global trading community. The hope would be for integrating them into the global community and global trading economic framework of the rest of the free world we would see reforms -- market

reforms, market access reforms, even human rights reforms. That has not been the case.

So they are getting a lot of the benefits of that deal but not living up to the obligations. But it is worse than that, because they are using their access and this increased integration to change the system and to change the game, and that is the real challenge, and I am glad that you have captured that with that turn of phrase.

You obviously make some pretty significant recommendations. Revocation of the PNTR is one that we have made here. Short of that, or even in conjunction with that, I want to explore some of your other recommendations.

I noticed in your testimony and some of your other writings what I would characterize as a robust skepticism of the high fence, small yard strategy, especially perhaps domestic investment to boost manufacturing here. So just some questions here. Should we restrict the flow of technology? Should we restrict the flow of capital to certain strategic sectors? And should we invest to boost domestic manufacturing capacity here in the United States and create and preserve jobs?

You do say in your testimony that it is imperative for the United States to create an environment to allow industry to flourish here at home. The question is, how do we do that? Can we do that simply by deregulation and further expanding energy production, or is there a role for targeted investment, and to use your phrase, what guardrails need to be put in place on that investment?

MS. DE LA BRUYÈRE: This is an awesome question, and precisely right, I am very skeptical of the high fence, small yard approach.

First, on the should we restrict technology to China question. You said this incredibly well. Restricting technology, or trying to restrict technology does impose costs on China. It can slow China's development of technology we don't want China to obtain. However, it is never actually going to work. We are never actually going to prevent China from developing technological capabilities in the modern environment, in one where we are operating in a globalized world where China is everywhere, and one where we are in an information technology environment and information technology flows across borders.

Because of that, I would argue that we can't think about tech denial as the core of our national strategy for competing with China in technology, and we can't over-invest in it in such a way that we are putting our resources into something that won't have the intended ultimate effect.

Where we can impose costs on China we absolutely should, but we should do that with eyes wide open about the effectiveness of doing it and what we are spending to that end, including on political capital as well as actual resources.

Proactive investment, we need to have production in the U.S., and the government does have a role in that. I would argue that, again, the U.S. government will never succeed in picking winners and losers. We won't be able to, through targeted government intervention, build a robust domestic industry in the U.S. And Solyndra is a compelling case, and I think we are at risk right now of creating a whole lot of even bigger Solyndras.

What we can do, as a government, is provide effectively public goods, but public goods that allow industry to work. So the list goes beyond what I mentioned in terms of energy and skilled workforce and permissive regulations. I think industry zones are a really compelling argument on this front. That is an infrastructure that can provide coordination across the private sector as well as the resources for production.

Is there room for targeted investment? Yes, but I think it is in a very specific set of things,

defined by two points. One would be immediate security relevance. The government provides security. That is a public good it does provide, and there is room for targeted intervention and investment from the government in those goods.

And the second would be the upstream of value chains. One of the big problems with how we have invested thus far, as a government, is that we have targeted mid- and downstream spaces in value chains that depend on China for their inputs, as well as for their markets, and therefore, we are just bolstering a player that is within Chinese-controlled value chain. I think that changes if you are investing in the upstream, and I think you can think about upstream components as part of the public goods that the U.S. government is providing for domestic industry.

COMMISSIONER GOODWIN: Thank you.

COMMISSIONER KUIKEN: Thank you, Commissioner Goodwin. Commissioner Miller.

COMMISSIONER MILLER: Thank you, Chair Kuiken. Mr. Lin, one area I don't think Congress or we, as a Commission, spend much time on is fusion. Can you give us a little bit more guidance on how we should think through the fusion competition with the PRC, fusion supply chains, and in particular, what our top policy priorities should be right now.

MR. LIN: Sure. Thank you for the question, Commissioner Miller. Fusion is really one of those interesting technologies where it is not yet at commercialization and has only recently broken through scientifically. At the Lawrence Livermore National Lab, December 2022, they finally proved that they were able to essentially get more energy out of the fusion reaction than they put into it through a laser pulse. This was a remarkable scientific breakthrough, and has shown more promise than ever before, the possibility of fusion being a commercializable technology.

Now beyond the innovation stage of fusion science comes the commercialization or the walk toward commercialization. At SCSP we recently stood up a Fusion Commission on the scaling of fusion energy. We have a report coming out in the coming weeks, so I don't want to get too much ahead of that.

But one of the key takeaways of it is that we have heard from industry partners and government is just the challenges of building a first-of-a-kind piece of infrastructure. How, as a company, how, as an innovator, do you build something where there are no rules that tell you, from a regulator perspective, what your guardrails are and what your left and right bounds are. And it is difficult to build something new when you don't know whether or not it is going to be in violation of some sort of regulation or license or permit going on into the future.

So I think that is a key area that we can streamline to enable, again, the commercialization of what could be a really groundbreaking, game-changing source of energy generation, that again, carries with it a whole slew of downstream implications for national power.

I think the risk here, though, is that we are seeing major moves on the China side in this tech area. In the recent weeks and months we have seen China making both scientific and literal groundbreaking achievements on fusion, on building fusion machines and reaching new levels of fusion science milestones.

And the key advantage here, again, is China's infrastructure-first approach toward many of these emerging technologies. They are able to cut through the regulations that stand in the way of some U.S. companies and private sector developers. They are able to devote an immense amount of capital, capital expenditures, infrastructure, cement, steel, manufacturing capability, to

build large-scale, Manhattan Project-scale projects.

So that is the risk that we see in this particular space. Yes, the U.S. was able to be the country that made the scientific breakthrough. We have to capitalize on that momentum and not fall behind in the scaling of that energy.

COMMISSIONER MILLER: Thank you. To Ms. de La Bruyère, your testimony notes that Washington's tools are out of touch with the arsenal at Beijing's disposal, and I would completely agree with that. But I think there is no case more challenging than batteries right now, in terms of do we compete, how do we cooperate, how do we compete with Chinese battery companies, particularly the United States. What guidance would you give to Congress, to automotive company executives, on how to make sure that we are not giving away the farm but not also falling behind in terms of batteries?

MS. DE LA BRUYÈRE: China weaponizes cooperation, and I think we have taken an approach to the competition with China broadly where we think we can hive off areas of competition and cooperation. And that doesn't work because China is so good at manipulating, quote/unquote, win-win environments to only its advantage.

Batteries, as you say, a great case of this, where I think we have really held out hope that we can maintain ties, we can maintain ties. And it has only been to our disadvantage, and China is climbing up that value chain.

The auto sector is at real risk, and I don't think we even realize the extent of that risk because China has started at the upstream and moved down, down, down in a way that tomorrow, especially, with energy trends changing, Beijing could just capture the entire global auto market. So what do we have to do? We need to have company- and government-level investments in the battery, in the auto, in the EV value chain, need to have actual restrictions, and real restrictions, against Chinese players. And we should cut waivers on those. We should get rid of delays on bans like the graphite one I mentioned. And we should extend restrictions to a wider range of possible ties to China. So not just majority-owned joint ventures. Any Chinese investment, any Chinese licensing agreements' operational ties.

And the auto sector, you said recommendations to the auto sector, it needs to wake up, like fast, because you can't carve out China supplying this part now but it is okay, we still have the downstream. And you can't carve out we have cheap production in China, so let's make sure there's still a relationship, or we sell into the Chinese market so let's make sure we still have a relationship. Any of that cooperation, that is just sacrificing future markets, and in a way that would be devastating for the domestic auto industry, and therefore, for America.

COMMISSIONER MILLER: Thank you.

COMMISSIONER KUIKEN: Thank you, Commissioner Miller. I think we actually have a briefing coming up from somebody on your fusion question, where China stands on it, which will be good.

I am going to pass it over now to Commissioner Price.

CHAIR PRICE: Thank you. One of my favorite parts about doing these hearings is when you are lower in the alphabet and all of your questions are asked. To Ms. Dohmen and Mr. Lin, I want to dig deeper on some of your recommendations. Both of you talk about investing in U.S. technological progress or bridging gaps.

If you had a magic wand that worked, what would this look like, with particular eye towards what is the public-private partnership, or what is funded in a public way, what is funded through private investment? How would this look? And maybe, Ms. Dohmen, you could go first.

MS. DOHMEN: Sure. Thank you for the question. I think there are a number of things

that the U.S. government could do. I will refer to three, in particular.

I think one is to invest in research and development in kind of the next generation of emerging technologies. So not just the technologies that we know now, but really what is next. What is next in semiconductor technology, for example. That is one.

A second one would be talent development through educational programs, workforce development programs, and improved immigration policies to make sure that we have the highly skilled immigration here in the country that we need to bolster our science and technology progress.

On the public-private partnerships, in particular, I think this is incredibly important in areas where we don't see the incentive for the private sector to invest themselves. So areas that are highly capital intensive, we have seen, just to point to the semiconductor industry again, a couple of decades ago we saw a lot of venture capital investment in semiconductors, but that has really dropped off as investments in software and AI and other technologies have become more attractive. Those are the kinds of areas where the private sector just doesn't have the incentive to put its money. The return on investment isn't very quick, and it takes a long time. Those are areas where I would like to see more U.S. public-private partnerships.

CHAIR PRICE: Thank you. Mr. Lin?

MR. LIN: Thank you, Commissioner Price, for the question, a very big question with a lot of ways to go with it. But maybe I will just outline a couple off-the-cuff thoughts. One example to look to is perhaps the way we are addressing the energy demands of AI, in the sense that I think there is a model in there of taking advantage of offtake agreements or putting forth government demand signals for a certain technology or a certain requirement that can set a pathway forward for that particular industry.

So in the case of AI data centers, we have seen vendors pledge to consume energy and thereby creating that demand signal for that energy, thereby creating the AI data center as a more secure investment. So setting the demand signal, I think, from government, is a first step.

And in one of the SCSP memos that we have laid out, we lay out five concrete steps that lay out a roadmap to winning the industries of the future, and one, it really begins with organization. On the government side, in the memo we propose the creation of a Technology Competition Council, which was a recommendation originally put forth by the National Security Commission on Artificial Intelligence. And the point here is really just, again, speaking to that government demand signal, a high-level government entity, prioritizing what the nation's technology priorities should be. And that sets forth industry, private sector actors, private capital, academia, the whole innovation ecosystem, to march in that direction. And I think that is an important first step.

In the interest of time I will just mention one or two others. One, to the point about diffusion, I think this is where the role of regional tech hubs or innovation engines, or whatever you want to call it, come in to play. Identifying or helping state and local governments, state and local innovators and entrepreneurs set up those regions or zones through a whole slew of incentives, credits, financial or other sorts of local-level industrial policies, to incentivize a technology hub that is already in the making. I think that is a key way to both capitalize on the innovation aspect of the technology cycle but also encourage diffusion across the nation, beyond just the bicoastal technology hubs.

CHAIR PRICE: Thank you both.

COMMISSIONER KUIKEN: Thank you, Commissioner Price. Commissioner Sims.

COMMISSIONER SIMS: Thank you, Mr. Chairman.

Mr. Lin, I love this chart that you gave us. I love a good Venn diagram. You know, this has sparked like a million things in my mind as I have looked through it. But one of the things I noticed is a lot of these technologies that are listed here -- and for the people that don't have it, the way that this Venn diagram is set up it lists technologies, and it says here are areas where China is leading, here are areas where U.S. is leading, and the areas that are contested in the middle.

If you look at almost all of these, all of them are dependent upon even more, I guess what I would call, foundational technologies. So I was just sketching one out as an example of what I am talking. So AI is dependent on chips, which is dependent upon production capacity, which is dependent upon access to lithography equipment, which is dependent upon access to lasers and sensor. I mean, you can just go on down forever and ever and ever on this.

So I think we often are inclined to pay more attention to things that are kind of sexy in the news right now. Everybody is talking about AGI and AI. But what are some of the technologies that are even more foundational than that, that maybe don't get discussed as often, that we should be paying more attention to in this competition with China?

We can start with you, Mr. Lin, and others if you have thoughts, as well.

MR. LIN: Yeah, sure. Commissioner Sims, thank you for that question, and you are absolutely right. There are some fundamental, foundational technologies that, by no coincidence, are also infrastructure heavy, and that is one reason why we haven't seen as much investment here in the U.S. into them as we have seen in China, because they require high upfront CapEx, capital expenditures, they require cutting through regulations, licensing, permitting, siting requirements that are necessary for them to break ground, and they have very slim profit margins. Chip manufacturing, for example, has a very, very low profit margin, and requires high yield to maximize profits there, which is why, up until recently, you hadn't seen much chip manufacturing happening here in the United States.

Trying to think ahead of your question, though, one of the things my team does at SCSP is trying to think over the horizon. So yes, thinking about today, things that we need are chip manufacturing, AI data centers, new forms of energy generation. Trying to think over the horizon, though, some of the things we have highlighted are non-terrestrial networks, LEO, low Earth orbit satellites, which, as you saw in the chart, we assess that the U.S. is in the lead. But China has just recently launched some of its first satellites, and is now on the board, so we can't let that leadership lead to complacency.

Bioreactors. Drew Endy testified in the hearing before us. Bioreactors or fermenters are a big infrastructure piece of how biotechnology innovation is done, and again, a very capital expenditure-heavy piece of infrastructure that requires a lot of upfront investments.

So those are just some of the ideas that I will tee up for the Commission for consideration.

COMMISSIONER SIMS: Thanks. Any others want to weigh in on that one? Yeah, go ahead.

MS. DE LA BRUYÈRE: I would absolutely reiterate that energy point. Obviously, energy fuels everything. Upstream materials are super important across every advanced technology field. They are an area that China prioritizes extensively, and also where China actually deploys a different strategic approach to its technology ecosystem than it does in other fields.

China is actually, in some, investing more in basic research for materials relative to applied research than in most other fields, than it does generally in its technological program,

precisely because those are so foundational and can drive leapfrog developments in the downstream of that tech value chain.

And also things that we might not even classify as technology, like manufacturing equipment. If you look at Chinese S&T and industrial plans, they stress CNC equipment, tools to replace manufacturing equipment, things that you can't make anything without and that we don't think about at all in our technological program, but are absolutely essential.

I think all of this speaks to, as you said, you can keep going down and down and down and down, and there are all of these things, and often there is no market incentive to develop them in an ecosystem China distorts, and that speaks to the difficulty of setting out an innovation or a technological plan from the top down, especially in a system like that of the U.S. We are probably going to miss things, and therefore I think speaks to the importance of letting markets find opportunity and investing accordingly in a working free trade system.

But I think your question also raises the other question of what are we trying to accomplish. We talk so much about, well, we are leading in AI, China is coming up, but what is AI? What is leading in AI? Why do we care about it? What are we trying to accomplish in technology? And is it the ability to control the foundation for other technologies? Is it the ability to apply technologies that may have been developed elsewhere? Or obviously this isn't my opinion, but is it first mover advantage? And I think thinking about that overall tech value chain demands the question of what is technological advantage and what do we want in it, which we should probably answer as we come up with a plan.

COMMISSIONER SIMS: Thank you all.

COMMISSIONER KUIKEN: Thank you, Commissioner Sims. Commissioner Stivers.

COMMISSIONER STIVERS: Mr. Khang, I strongly agree with your recommendation on reforming H-1B and permanent residency policies. This is your last recommendation. The current reality is that the best and the brightest are studying here in the United States and then don't have any kind of permanent residency, so they have incentives to go to China or other countries to be successful and to innovate. It is impossible to compete with that kind of a broken system that we have.

I would love for you to talk more about that. But my specific question is what is more of a concern right now -- students and researchers who are already here that are linked to PRC military or other institutions, or those who study here and then go on later to join one of those institutions? How do I understand the dynamic there? Which one is more of a concern?

MR. KHANG: I do not think that the vast majority of students and scholars who come over to the United States to study or to work here come with a nefarious intent of taking technology from the United States and serving the motherland. For the most part, they want to come to the United States because this is America, and they want to study here at the best universities. And then there are forces that are attracting these students, coupled with our broken system that is pushing them away, and that combination allows some of these students no option but to go back.

I think one of the most unfortunate things that I see are the best and the brightest get caught up in the lottery system and they can't stay here even though the company wants them, even though America wants them, because of this lottery system.

So this recommendation has probably come up multiple times, and of course it has been very difficult to address and fix. But we do need to switch to a merit-based system, a merit-based system that lowers the barrier for what it means to have extraordinary ability. One of these EB-1, -2, and -3 systems, right now the bar for what is considered extraordinary ability in the STEM

fields is quite ridiculous. I think that if you have a list of, let's say, technologies that America wants, greenlight some of those technologies, and if you work in those STEM field then you qualify, or at least get a better leg up to be chosen in these systems.

To come back and answer your question, I do think that there is a pattern of students graduating in prestigious universities in the PRC, getting a master's degree and Ph.D. in a prestigious U.S. university, working for two to three years, and then going back on a talent program. That is a pattern we see over and over again.

So I would say that these patterns, though, started at a source around 2014, 2015. This wasn't a pattern before. Most of the people who came over in the 1970s, the first CUSPEA people that came over from the PRC as physicists to come to the United States, they didn't leave. Most of them are still here. These incentives were skewed towards the PRC as the PRC developed these talent attraction policies, and we did nothing about it.

So H-1B is a great example of our broken system just pushing people away and having China add them.

COMMISSIONER STIVERS: Some would argue that there should be restrictions on PRC students studying in STEM fields in the United States. How would you respond to that?

MR. KHANG: I disagree with that. The best and the brightest of the PRC system in schooling, from middle schools to high schools, they want to come to the universities here and study. The problem is not to try to bar them. It is trying to attract them and say, "Hey, look, you can have freedoms here. You can get citizenship here. You can become an American." That is how I came over, and I am an American, a very proud one myself. It's because those incentives were there for me.

And I think if you turn this around and not look at it as restrictions and restrictions but emphasizing how attractive we can be, with some pointed policies, I think that we can again revive the American dream.

COMMISSIONER STIVERS: Thanks for that. I am going to turn to graphite. China has threatened restrictions on graphite in response to President Trump's 10 percent tariff announcement. Ms. de La Bruyère, and Ms. Dohmen also, do you believe that maybe in the long term that wouldn't be so bad in terms of building our own self-sufficiency? Ms. Dohmen makes the case, in her testimony, that export controls can be counterproductive when it empowers China to become self-sufficient with indigenous innovation. How would you answer that?

MS. DE LA BRUYÈRE: I think there are times when China certainly, at least its messaging can be its own worst enemy, and so yes, absolutely, and so should the very fact that China is threatening that. I think the private sector across the world needs to internalize the fact that China is not a trusted partner and isn't operating according to market forces, and that means they can't afford to rely on China.

I'd also argue, though, that generally -- so big picture, absolutely yes, if properly internalized. The trend up to this point has been that China threatens restrictions, for example, on graphite, in a way to pressure the U.S. government as well as to pressure U.S. companies to pressure the U.S. government. It doesn't actually follow through on them, so those threats serve only to undermine U.S. protections and don't cause the reworking of supply chains that they should. That said, the messaging should be internalized by the private sector, and it can be positive for our capabilities.

COMMISSIONER STIVERS: Thanks. Ms. Dohmen -- sorry, I am a little over time but I wanted you to answer that too.

MS. DOHMEN: Sure. I will keep it brief. Thank you for the question. I actually agree

with a lot that you have already said so I will just add on very quickly. I think we just need to do a better job of actually studying what we call, at CSET, kind of reverse chokepoints. So what are the chokepoints that China could be able to potentially use against us, whether it is in critical minerals or whatever have you. We need to make sure that we know what those are, the way that China is studying to figure out what their chokepoints are, and to figure out where China might have leverage.

So I think more work needs to be done on that, and it is an area where an open source research center, for example, like I mentioned in my recommendations, would be able to help pull people together that have the technical expertise, the language expertise, and be able to drive that kind of open source research to design policies to help mitigate the risks.

COMMISSIONER STIVERS: Thank you.

COMMISSIONER KUIKEN: I think there are a couple of Commissioners that want to have a second round. We will go to Commissioner Miller first, and then Commissioner Price.

COMMISSIONER MILLER: Thank you. We have a lot of experts coming in today, in different fields of expertise, and I intend to ask each one of them a simple question, requiring a very brief response. How would you best characterize export controls and key technologies in the areas of your expertise? Would you call it absolutely critical? Useful? Not important? Or counterproductive?

And while I want to get each of your answers, I want to end with Ms. Dohmen, because she wrote a very compelling, very interesting, I would say, *Foreign Affairs* article a number of months ago, in which she said, "The main problem for Washington is that export controls may inadvertently accelerate the development of China's domestic semiconductor industry, also that export controls will probably spur China's semiconductor industry to catch up with market leaders."

I think it is an interesting point to make if it is 2015, and we hadn't started down the export control process. Now that we are 10 years later, it seems almost impossible to imagine a hypothetical where the Chinese would reverse that process anyways, even if the United States were to stop export controls and announce that they were reversing them.

So I would like to get each of your responses, maybe down the line, but end with Ms. Dohmen, just a little bit of context on why you think this would possibly apply in this day and age. Thank you.

MR. KHANG: I would say useful if we close the loopholes that are in our export controls. And I agree with you that the argument that says export controls will spur more innovation in China rings hollow to me, because they are going to do it anyway.

MS. DE LA BRUYÈRE: Useful but as dressing on top of a much more robust policy for technological competition, and without assumptions about their effectiveness.

MS. DOHMEN: I would say somewhere between useful and important, with the emphasis on the fact that we just need to focus on running faster here. That alone is just simply not going to be enough.

To respond to your point about -- and also to Tim's response -- I do not deny that that has certainly been the case. China's self-sufficiency efforts, especially in the semiconductor industry, have been a key driver for the last, you know, decades really.

The point that I want to make here is that it is not that China wasn't already innovating and driving towards self-sufficiency. It is that there is now more of a necessity to actually do so. Previously, the Chinese government was pushing for more collaboration within, let's say, the semiconductor industry to work together.

But the problem was the Chinese companies still had access to foreign suppliers, and with that access to foreign suppliers the downstream companies that were supplying the tools or trying to innovate and create a domestic industry for the tools didn't actually have really a market to sell those to. And the semiconductor industry is actually very integrated, and there is a lot of co-development up and down the supply chain. And to actually innovate and progress and diffuse the technology and make it useful on the fab lines, you need that collaboration, and the fabs need to be willing to actually work with their tool manufacturers.

Now we have a situation where there are pilot lines at fabs specifically to focus on that domestic innovation. So what I am saying is it is not that there weren't self-sufficiency efforts before. It is just more of a necessity now. And yeah, I think it has just accelerated that push.

And I apologize. I know you wanted me to go last, so apologies about that.

MR. LIN: Maybe just to build off that point, taking advantage of the gray scale, I will put it somewhere between useful and critically important.

Export controls are a depreciating asset, so the longer we wait to use them, the less effective they will be, just due to the pace of technology and technological innovation.

To some of my fellow panelists' additional points, they must be carried out in coordination and conjunction with other tools that we have in the toolkit, inbound investment screening, outbound investment restrictions, market restrictions, market access restrictions, just to name a few. But it is not the only tool that we have in the toolbelt. It has to be complementary with some of the other tools that we have.

COMMISSIONER MILLER: Thank you for those answers, and also the clarification. And also there is an awareness that as you come in here and testify and try to convey an important message that you want to make sure you are not talking export controls, export controls, export controls, because you lose the message of pushing the positive and the offensive side, in some ways, the pushing innovation and driving harder and driving faster.

So thank you all for your answers.

COMMISSIONER KUIKEN: Thank you, Commissioner Miller. Commissioner Price, and then we will go to Commissioner Sims.

CHAIR PRICE: A very simple question. The name of this hearing is "Made in China 2025--Who is Winning?" And we have heard a lot of glass half empty, glass half full. So I just wanted to give you each an opportunity to answer that, in less than a paragraph, but more than one word if you would like, just to make sure we are all pretty clear.

Maybe I will start with Mr. Khang and we will go down the table.

MR. KHANG: I thought about this question because winning can be a gerund or it can be a continuous verb. Who is doing a lot of the winning right now, continuously, is China. However, I do believe that the United States is still ahead.

MS. DE LA BRUYÈRE: Not a grammar gal, but China, on both the gerund and the continuous verb. We can't make without China. China can make without us.

MS. DOHMEN: Since my area of expertise is mostly in the semiconductor industry I will stick to that. We are still ahead, but we are buying time, and we have a window of opportunity. So I will just re-emphasize that we just need to focus on running faster here. So I would say currently winning, but it is a window of opportunity that we need to take advantage of.

MR. LIN: I would say if we are centering Made in China 2025 strictly around manufacturing, China is winning. However, I think one key takeaway should be, for the U.S., that if we combine our innovation lead that we have demonstrated with things like ChatGPT, with mRNA vaccines, our innovation capacity, combined with some investments in

manufacturing, that can really push us ahead. So it is two sides of the same coin.

CHAIR PRICE: Thank you all.

COMMISSIONER KUIKEN: Thank you, Commissioner Price. Commissioner Sims.

COMMISSIONER SIMS: I am back on Mr. Lin's beautiful Venn diagram.

COMMISSIONER KUIKEN: I am going to ask a question there in a second.

COMMISSIONER SIMS: So in the contested space you have semiconductors listed, and you have an arrow indicating the direction you think that competition is going. And in this particular instance you feel like by 2030 we will be trying to get it outside of contested into more like we are winning that space. And I am curious how that assessment might be impacted by a Taiwan move by China, if they were to forcefully take Taiwan, how that would impact that assessment.

MR. LIN: Okay, yes. Well, a Taiwan contingency would be game-changing for obviously not just semiconductors but for the global economy. As you are rightfully hinting at, a majority of the world's chip manufacturing happens on the island of Taiwan. We have seen some successes of the CHIPS and Science Act pushing some of that chip manufacturing off the island, and I think just recently Taiwan -- and Hanna, please correct me if I am wrong -- the Taiwanese government just authorized TSMC to offshore some of its most leading edge, like two-nanometer, chip manufacturing outside of the island, which up until this point had not really been discussed because Taiwan sees that as one of its key strategic assets.

So yeah, without a doubt, a Taiwan contingency would throw the semiconductor supply chain into a whirlwind, let alone the global economy. But again, we are starting to see some silver linings that first China expressing at least an open-mindedness, willing to offshore some of its leading edge chip manufacturing, and again, some successes from CHIPS and Science to onshoring chip manufacturing here in the U.S.

COMMISSIONER SIMS: Ms. Dohmen, do you want to add anything to that?

MS. DOHMEN: No. I mean, I agree with a lot of what Mr. Lin has already said, and I think the CHIPS and Science Act, in particular, to go back to the argument that was previously made, what the CHIPS and Science Act is doing, or the manufacturing incentives, in particular, and the tax credits, is creating not just an opportunity for companies like TSMC to invest here and bring those fabs here, those leading edge fabs, it is also an opportunity to create clusters of that kind of technology development here. And we have seen a lot of that already happening in just the few years since the act was passed. And I think that is exactly where we need to be headed to kind of mitigate the risks in case of a Taiwan contingency. But, of course, the effects of that would be far beyond the semiconductor industry.

COMMISSIONER SIMS: Yeah. One last question. So the one surprise in this Venn diagram, to me, was that AI was not put in the U.S. leading category but was in the contested category. And the reason I was surprised by that is even with DeepSeek R1, I think it is pretty clear now, as we learn more about it, that it was distilled from ChatGPT, and not that LLMs are the be-all, end-all in the AI world.

But it feels like, to me, historically China has struggled in competing with America's innovation economy, that they are a lot better at stealing stuff than they are making stuff. Obviously, it is a terrible thing, but from an innovation standpoint they are always a little bit behind, because if you are relying on stealing other people's IP instead of making your own, by definition, they are going to stay ahead of you a little bit.

And that is kind of how I have been thinking about the AI space. So am I thinking about that the wrong way, and why would you kind of say that AI is in a contested area now rather than

us being in the lead?

MR. LIN: Yeah. Maybe I will riff off of what you are saying about China stealing U.S. IP, which China has had a long history of this, going back to ever since I started watching China, going back to 2010, when cyber operations was kind of the forefront of the policy discussion in the bilateral relationship.

But maybe if I could encourage you to maybe think a little differently from the stealing to the -- so thinking of China rather than being purely an imitator, China is an iterator. Dan Wang wrote a great book, and wrote a great article in *Foreign Affairs*, where he introduces this idea of process innovation.

So, correct, China has not yet, or has not replicated the U.S. success in introducing true, scientific breakthroughs that have revolutionized the world, going back to mRNA vaccines, going back to ChatGPT, going back to the iPhone. But what China has done is taken these innovations, and thanks again to its manufacturing prowess, been able to iterate on these things to make it better, faster, cheaper. And we are seeing that unfold before our eyes with DeepSeek's R1, in that they are able to take some of the foundational U.S. innovations, in the software space now, take those innovations, iterate on them, and make them cheaper and faster and better. So I think that is the future trajectory that we are headed in now.

COMMISSIONER KUIKEN: Commissioner Friedberg has told me he does not have any more questions, so I will take the last one before we all go get lunch.

First of all, there have been some great quotes on this panel. I think Randy and I have been writing them down. David, you just landed one: "China is an iterator." Emily, you had, "China weaponizes cooperation." And then, David, you did, "Export controls are a depreciating asset," which is a fantastic sort of way to think about things.

My question is, I am glad Commissioner Sims held up that chart. We just heard from Dr. Endy on the last panel that we are losing badly in pharmaceuticals, and we are if not totally losing in synthetic biology we are about to be losing. He gave Commissioner Price the idea of the 1,000-day race, gave us some very specific ideas.

You guys -- SCSP, I don't want to say you guys -- have biotech and pharmaceuticals in the U.S. is crushing it category, which sort of demands a response. And I don't mean that in a nasty way. I just mean I welcome your feedback on that one.

MR. LIN: Yeah. I think for the Venn diagram, in particular, we break biotech into two areas -- synthetic biology and biopharmaceuticals. Biopharmaceuticals, I think, again, lends itself towards China's manufacturing advantages. Lots of pharmaceutical ingredient contract manufacturers are based out of China, look to China to build the key pharmaceutical ingredients, KPIs. So I think from that vantage point China is definitely ahead.

Synthetic biology I think lends itself to U.S., to America's innovation advantages. I am not super deep on that subject but I will say that was one of the key considerations that put that particular technology on the U.S. side.

COMMISSIONER KUIKEN: That was a good answer. So it is still different than what Dr. Endy told us, which is that in the biopharmaceutical space he has basically said that they have done -- and this goes back to Commissioner Sims' comment about the foundational layers. It sounds like in the foundational layers, in biopharmaceuticals, that the U.S. basically is totally or nearly totally dependent on China. So the concept that we are leading in the biopharmaceutical space just doesn't seem to hold water.

MR. LIN: Absolutely. I take your point, Commissioner Kuiken. I think one technology we can lean into to perhaps leapfrog there over China's systemic advantages there is, again,

going back to AI. The prospects that AI has for biotechnology are yet to be defined, but very hopeful, variable to potentially apply AI to biotech R&D to discover new biotechnological frontiers.

So applying AI to biotech I think is really the next phase of the biotech competition writ large.

COMMISSIONER KUIKEN: All right. Thank you very much to everyone on the panel. And I believe we are going to reconvene at 2:00. No, no, you are all done. Thank you very much for coming. You guys all get to go. Thank you.

[Recess.]

PANEL III INTRODUCTION BY VICE CHAIR RANDALL SCHRIVER

VICE CHAIR SCHRIVER: Good afternoon. Welcome back to my fellow Commissioners.

Our third panel, and final panel of the day, will examine the types of industrial policies China has pursued to advance its Made in China 2025 goals.

We will start with Ms. Liza Tobin, who is the Managing Director of Garnaut Global, and Senior Fellow at the Jamestown Foundation. Ms. Tobin will testify on how China's all-out industrial policies create a unique system of brute force economics.

Then we will hear from Dr. Barry Naughton, who is joining us virtually. He is the So Kwan Lok chair of Chinese International Affairs at the University of California San Diego's School of Global Policy and Strategy. Dr. Naughton will discuss how a step change has occurred over the past five years as Chinese policymakers increasingly emphasize technological self-reliance.

And then finally we will hear from Dr. Kyle Chan, Postdoctoral Research Associate at Princeton University. Dr. Chan will assess how China's foreign technology acquisition, its use of multiple simultaneous industrial strategies, and its export-led development model have aided China's technological and industrial development.

So thank you all very much for your testimony, and I ask our witnesses to keep remarks to seven minutes.

Ms. Tobin, we will start with you.

OPENING STATEMENT OF LIZA TOBIN, MANAGING DIRECTOR, GARNAUT GLOBAL, AND SENIOR FELLOW, JAMESTOWN FOUNDATION

MS. TOBIN: Good afternoon. Vice Chair Schriver, Commissioner Kuiken, members of the Commission, and to everyone else joining us today, thank you so much for the opportunity to testify before you on this topic.

Manufacturing is China's key strategic advantage over the United States. Now nearly everybody knows that China is the world's factory, but what is less widely understood is that China is translating its manufacturing prowess into innovation power. The results are clear, and I know you have already talked about them this morning.

China has surpassed the United States in technologies like 5G, hypersonics, electric vehicles, and batteries, and is making rapid progress in AI and biotechnology. In robotics, one of the key sectors identified in Made in China 2025 ten years ago, the PRC has vastly exceeded its goals. By 2023, China was deploying more industrial robots than the rest of the world combined.

Beijing has obliterated the myth that used to prevail in Washington a few years ago that China can't innovate, that it can only borrow and steal technology.

What China is doing is combining legitimate tactics, like large investments in education and infrastructure, with unfair play. Beijing's approach reminds me of a schoolyard dynamic that we all recognize, the big kid who combines legitimate strength with unfair tactics to dominate the playground. I call this brute force economics, and it has three characteristics.

First, force. Beijing can bring together the entire party state apparatus to achieve its strategic ends, so our firms aren't competing with their individual peers in the Chinese system but rather with an entire ecosystem that Rand scholar, Jude Blanchette, has called "CCP Inc."

Second is scale. As the world's second-large economy, China wields both an enormous market and massive resources for industrial policy.

And then third, ruthlessness. The CPP approaches economic competition as a zero-sum game -- so think economic espionage and predatory trade practices -- and it consistently fails to meet its international commitments.

Americans usually respect a tough competitor, but China's combination of ingenuity, predation, and scale has confounded policymakers.

Beijing's lead in manufacturing presents two urgent challenges for us. First, we are not prepared for a prolonged conflict with our primary rival. Our defense industrial base now depends on a potential adversary for numerous critical materials like energetics and semiconductors. And second, we are at risk of losing the next industrial revolution. AI is coming together with physical industry to transform manufacturing. If there is one thing I would like you to take away today it is the idea of industrial AI.

Advances in generative AI have brought surprising innovations to cognitive tasks, and we all see this every day, in ChatGPT and other LLMs. Now think about applying that kind of innovation on the factory floor, to physical and mechanical tasks. Imagine someone without any coding background using an iPad to quickly design a digital prototype for a specialized component that goes into a drone, and then get it into production within days, rather than weeks and months.

But we are not set up to fully benefit from these trends. How do we turn this around? I would argue that we are in a moment of unique historical opportunity in our contest with China. At the same time as this new industrial revolution is unfolding, many companies are looking for opportunities to diversify out of China, to less risky places.

So how do we make that happen? Just as dealing with the schoolyard bully requires building our own strengths, standing up to abuse, and teaming up with friends, responding to China's brute force economics requires a three-part strategy.

The first is obvious. We talk about it a lot -- promote. It is time to re-industrialize. We have already made a good start with semiconductors, with the CHIPS Act, but we need a much broader manufacturing renaissance. Only 12 percent of our factories use advanced robotics. We need an action plan that matches the scale of this challenge and targeted incentives to drive widespread technology adoption.

Second, pushback. We need to defend against these predatory practices, and for the sake of time I will save my ideas here for the Q&A.

Third, we need to pool our resources with allies. To overmatch China's ability to weaponize its market we need a dual-track system that leverages democracies' combined market power. We need a new vision for trade: more trade with friendly counties that play fair and less trade with the world's biggest cheater.

We can take inspiration from the pre-WTO General Agreement of Tariffs and Trade, which was based on the principle of free trade for free nations and managed trade for autocracies. This means preferential treatments for partners who play fair and strict guardrails around trade with rivals.

In an age of cyber physical systems, power flows to those that control both code and steel. An American response to China's industrial strategy must include a manufacturing renaissance. This can secure our economic vitality, our ability to deter conflict, and strategic leadership in the decades ahead.

Thank you very much, and I look forward to the questions.

PREPARED STATEMENT OF LIZA TOBIN, MANAGING DIRECTOR, GARNAUT GLOBAL, AND SENIOR FELLOW, JAMESTOWN FOUNDATION

Testimony before the U.S.-China Economic and Security Review Commission Hearing on "Made in China 2025 – Who Is Winning?"

Thursday, February 6, 2025

Liza Tobin
Managing Director, Garnaut Global LLC and Senior Fellow, Jamestown Foundation

Members of the Commission, thank you for the opportunity to provide you with my testimony.

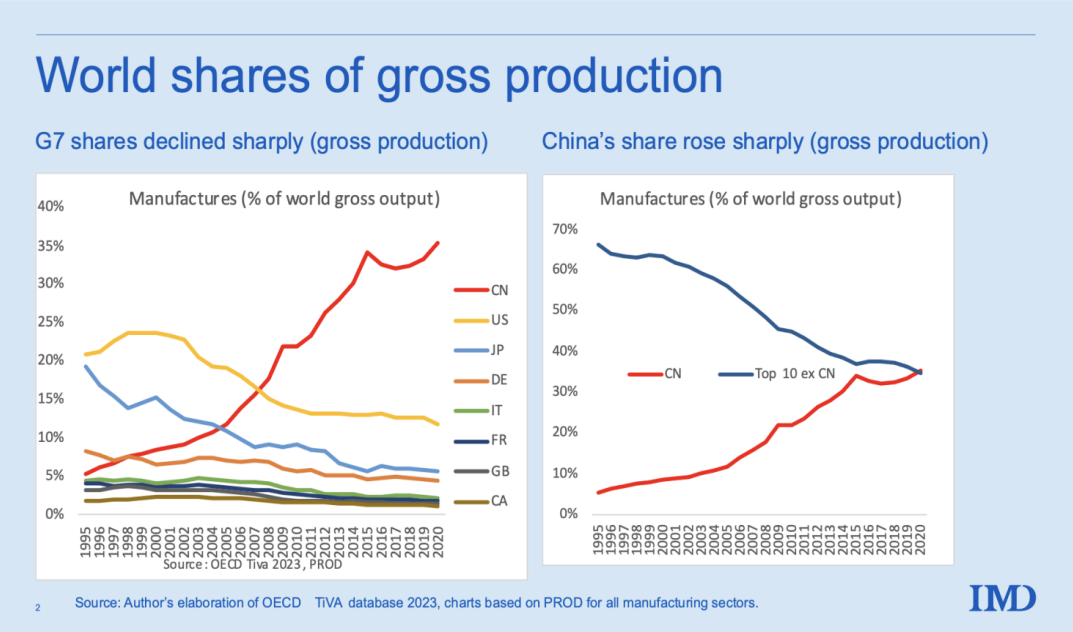
Manufacturing is China's key strategic advantage over the United States and its allies, a reality that remains underappreciated in Washington. Over four decades, as America's industrial base withered, the People's Republic of China (PRC) built unmatched manufacturing capacity that spans the entire value chain at massive scale. This positions it to outmatch the United States in wartime production during a protracted conflict. It also gives it significant leverage in the emerging industrial revolution, where AI is transforming physical industry. This is happening even as China experiences an enduring economic slowdown. Industrial might now lies at the heart of Beijing's challenge to American power.

China's Rise as a Manufacturing Superpower

The PRC's techno-economic strategy represents one of the most systematic and ambitious efforts in modern history to reshape the distribution of global economic, technological, and military power. The PRC's rise to global manufacturing dominance occurred at an unusually rapid pace by historical standards. While the United States took nearly a century to surpass British manufacturing before World War I, China's ascendance has been meteoric. In 2001, the PRC accounted for roughly nine percent of global gross manufacturing output. By 2020 it accounted for 35 percent, with gross output nearly three times that of the United States (12 percent), six times that of Japan (6 percent), and nine times that of Germany (4 percent).[1] This dominance extends across both traditional and advanced sectors. China has evolved from primarily producing textiles and clothing in 1995 to becoming the leader in electronics, basic and fabricated metal products, and chemicals and pharmaceuticals by 2020.[2] Meanwhile, over the past four decades, America's share of global high-tech manufacturing has fallen from 40 percent to 18 percent.[3]

[1] Richard Baldwin, "China is the world's sole manufacturing superpower: A line sketch of the rise," VoxEU (2024).
[2] Ibid.
[3] Brady Helwig, Addis Goldman et al, "National Action Plan for United States Leadership in Advanced Manufacturing," SCSP (2024).

China is translating its scale advantages into innovation power: control over manufacturing processes shapes how technologies evolve, which innovations can scale, and who can access critical capabilities. For the United States, this represents a fundamental shift, as our own economic output is now heavily dependent on industrial capacity controlled by our primary strategic rival.



Graphic Source: Richard Baldwin, "China Is the World's Sole Manufacturing Superpower: A Line Sketch of the Rise," VoxEU (2024)

Manufacturing in PRC Strategy

Manufacturing has always been central to the PRC's national strategy, a fact reaffirmed in recent Chinese policy guidance highlighting manufacturing as "the main battlefield" for leading the next industrial revolution.[4] Made in China 2025 (MIC 2025), launched in 2015, captured significant attention in Washington because it set explicit goals for capturing domestic and global market share in strategic sectors. But it is only the tip of a broader and more deeply entrenched strategic approach spanning decades and many strategies, policies, and Five Year Plans. An early but noteworthy example is the 2006 Medium and Long-Term Plan for Science and Technology Development, a critical marker in the CCP's emphasis on indigenous innovation.[5]

[4] "Implementation Opinions of Seven Ministries Including the Ministry of Industry and Information Technology on Promoting the Innovative Development of Future Industries," CSET translation (2024).
[5] I address these PRC plans and strategies further in my 2023 testimony to the Select Committee on the CCP here.

The CCP's plans are not static; Beijing regularly takes stock of emerging technologies with potentially strategic characteristics and updates its priorities accordingly. The 2024 Implementation Opinions on Promoting the Innovative Development of Future Industries, for example, targets cutting-edge technologies such as biomanufacturing, brain-inspired technologies, nuclear fusion, and quantum computing. Manufacturing is a through line, emphasized as crucial for capturing the transformational potential of all these technologies.[6]

PRC industrial strategies and policy documents reflect Xi Jinping's directive to "actively seize the commanding heights of technological competition,"[7] representing a long-term vision for achieving techno-economic supremacy. While not all Chinese initiatives succeed, the robotics sector – one of ten key areas identified in MIC 2025 – demonstrates remarkable progress. Under the Robotics Industry Development Plan (2016-2020), China not only met but vastly exceeded its production target of 150,000 industrial robots annually, reaching 237,000 units by 2020 and 363,000 in 2021.[8] The country has made significant progress toward reducing its historical dependence on imported robots – Chinese firms met more than half of domestic demand in early 2024. By 2023, China was deploying more industrial robots than the rest of the world combined[9] and today is positioning itself to wipe out foreign competition as it has done previously in sectors like electric vehicles and solar panels.[10]

This robotics push serves dual strategic purposes. Domestically, it helps offset China's demographic challenges, as the country's working-age population has declined by 14 million since 2016, threatening labor-intensive manufacturing. Internationally, it advances China's aim to dominate global supply chains. The 2016 Chinese takeover of German robotics giant Kuka served as an early warning of these ambitions. While it prompted stricter investment screening in Western nations, it failed to catalyze a comprehensive strategic response from the United States and its allies. Today, American technologists and venture capitalists are excited about robotics, but it is not a significant focus for U.S. policymakers. Without intervention, the United States is on track for its robotics sector to become heavily dependent on Chinese components.

The CCP's technology plans are inherently dual-use and support the party's broader national objectives. The Military-Civil Fusion (MCF) strategy, designed to erase boundaries between military and civilian sectors and enshrined in PRC law, illustrates this.[11] MCF has evolved to focus on building what Chinese strategists call an "integrated national strategic system and

[6] "Implementation Opinions of Seven Ministries Including the Ministry of Industry and Information Technology on Promoting the Innovative Development of Future Industries," CSET translation (2024).
[7] Xi Jinping, "'Strive to Become the World's Primary Center for Science and High Ground for Innovation," March 18, 2021; translation by DigiChina.
[8] Angela Shen and Lily Ottinger, "China's Leap into Robotics for Industry," China Talk (2024).
[9] Robert D. Atkinson, "China Is Rapidly Becoming a Leading Innovator in Advanced Industries," ITIF (2024).
[10] Erik Britton, "China is Waving in the Robots," Fathom Financial Consulting (2024)
[11] The National Defense Law (revised 2020) Article 34 stipulates that "science, technology, and industry for national defense shall follow the principles of civil-military integration, peacetime-wartime integration, priority to military products, and innovation-driven, independent, and controllable development." https://web.archive.org/web/20250130000133/http://www.mod.gov.cn/gfbw/fgwx/flfg/4876050.html

capabilities"[12] – an overarching framework designed to harness all state and societal resources to achieve the CCP's ultimate goal to make China the "global leader in terms of comprehensive national power and international influence."[13] The CCP viewed its COVID-19 response as a successful test of this system, with the pandemic enabling the party to implement and retain new forms of social control – from community-based surveillance to militarized robots – that blur the lines between wartime and peacetime governance. Party leaders celebrated whole-of-nation, pandemic-era mobilization efforts as validating their "People's War" approach to crisis management, while using it to advance their broader narrative of governance superiority.[14]

The party's newest focus is on dominating not just production but also the tools of production themselves – the base layer of machines, materials, and systems that determine who can manufacture and who cannot and who reaps the benefits of innovation. Control over the tools of production will grant Beijing still greater power over the future of production.

Tactics: Brute Force Economics

For years, U.S. policymakers, myself included, have grappled with Beijing's complex fusion of industrial strategy and predatory practices. What makes this a particularly vexing policy challenge is how the CCP blends legitimate competition with unfair and even ruthless tactics. This combination has often stymied American policymakers, whose natural tendency to respect worthy competitors makes them hesitant to confront even obvious predation or take actions that could be perceived as trying to slow China down.

To capture the unique features of this challenge, I coined the term "brute force economics" as an analytic frame to sum up "the aggressive, evolving, and often opaque web of policies and tactics that Beijing employs to give its national champions—corporations acting to advance government policy—an advantage and seize a dominant global market share in strategic sectors."[15] Brute force economics shares characteristics of garden-variety mercantilism and industrial policy used by many nations, but is distinguished by three characteristics:

- **Force:** Beijing can marshall the full force of the party-state apparatus – including military, intelligence, and diplomatic actors; state-owned enterprises, and private sector entities, universities, and military and intelligence capabilities – toward strategic

[12] Liza Tobin, Addis Goldman and Katie Kurata, "Beyond Fusion: Preparing for Systems Rivalry," War on the Rocks (2024).
[13] Xi Jinping, Work Report to the 19th Party Congress, October 18, 2017, in *The Governance of China,* volume 3.
[14] Liza Tobin, Addis Goldman and Katie Kurata, "Beyond Fusion: Preparing for Systems Rivalry," War on the Rocks (2024).
[15] Liza Tobin, "China's Brute Force Cconomics: Waking Up from the Dream of a Level Playing Field," TNSR (2022).

objectives.[16] Xi Jinping has touted this feature, saying, "Our greatest advantage is that our country's socialist system can concentrate resources to accomplish great undertakings."[17]

- **Scale:** As the world's second-largest economy, China wields two powerful tools: a market that other nations can't ignore, and massive resources for industrial policy. In 2022, Beijing's $248 billion in industrial policy spending dwarfed comparable U.S. and European efforts.[18]

- **Ruthlessness:** Beijing approaches economic competition as a zero-sum game, targeting smaller countries with economic coercion, and has consistently fallen short of fulfilling its international commitments. While U.S. officials have invested extensive time negotiating joint statements, frameworks, trade agreements, and other bilateral accords across various domains of mutual interest, the PRC's track record of implementation ranges from poor to theoretical.

In sum, China's brute force economics distorts activities that are usually thought of as positive sum – trade and technology cooperation – and turns them into zero-sum games. The United States and its allies need to abandon the notion that competing on a level playing field with China's state-led economy is possible and build policies that account for this unfortunate reality.

Future Prospects

Beijing's decades-long pursuit of technological self-reliance has yielded significant results, with the PRC surpassing the United States in areas such as 5G, hypersonics, minerals processing, and EVs, and establishing a lead in 6G development with more patents than the United States. It is making fast progress in other areas such as AI and biotechnology.[19]

The Party is determined to lead the fourth industrial revolution, but faces new headwinds: China's success thus far has depended on strong economic growth and access to foreign technology, expertise, and capital—resources that are becoming increasingly constrained as democracies restrict access and China's economy enters a structural slowdown. Traditional growth drivers like real estate and infrastructure are waning, while demographic pressures mount.

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[16] For a case study, see, e.g. "TikTok: A Threat to National Security," Jamestown Foundation (2024).
[17] The phrase is 我们最大的优势是我国社会主义制度能够集中力量办大事. Xi Jinping, "The Distinctive Advantage of Being Able to Concentrate Resources to Accomplish Great Undertakings," www.cpcnews.cn, May 15, 2020.
[18] Liza Tobin, "China's brute force economics: Waking Up from the Dream of a Level Playing Field," TNSR (2022).

[19] For assessments of U.S. vs. PRC leadership in key technologies, see David Lin et al, "Mind the Gaps," SCSP (2024), and Robert D. Atkinson, "China Is Rapidly Becoming a Leading Innovator in Advanced Industries," ITIF (2024).

Policymakers in Washington and allied capitals would be unwise to assume that China's slowing economy diminishes the urgency of a strong response. Beijing's capacity to pursue its military and technological ambitions should not be underestimated. Even with reduced growth, the world's second-largest economy can still direct massive resources toward strategic objectives, achieving dominance in targeted sectors even amid broader economic challenges. While decoupling must over time constrain Beijing's ability to pursue its ambitions, timing is uncertain and China's technological capabilities and industrial base may have already reached a critical mass to outpace the United States across a growing array of sectors. This evolving reality demands close attention from policymakers and analysts—particularly to China's transition from "fast follower"" to "peer competitor" and "leader" in key technologies, the CCP's assessment of its comprehensive national power relative to the United States, and how these shifting dynamics could shape its strategic behavior and willingness to take provocative action. Understanding these trends will be crucial for democracies to maintain a technological edge and shape a future that advances both innovation and freedom.

Implications for the United States and Its Allies

The Arsenal of Autocracy has eclipsed America's Arsenal of Democracy. This creates two urgent challenges for our industrial base:

- **Wartime Production:** We are unprepared to sustain a prolonged conflict with our primary strategic rival. The U.S. defense industrial base now depends on a potential adversary for critical inputs, from rare earth minerals to advanced electronics and even the energetic materials used in explosives for weapons.[20]

- **The Next Industrial Revolution:** We risk losing the next industrial revolution, which is unfolding as AI converges with physical industry to transform how things are made.

But we still have a window of opportunity to turn this situation around. The convergence of two trends — an AI-driven industrial revolution that is transforming manufacturing, and decoupling from China — create a window of opportunity to rebuild American industrial might, leveraging American advantages in finance, software, disruptive innovation, and a global network of allies and partners. But this window is finite.

Policy Recommendations

The U.S.-China tech race will be won by whoever can innovate, produce, and deploy technology at scale. As code fuses with physical systems and algorithms direct assembly lines, China's control of manufacturing gives it a crucial advantage. While America leads in finance and software, China's industrial might has enabled it to surge ahead in critical emerging technologies.

[20] Nadia Schadlow, Brady Helwig et al, "Rocket's Red Glare: Modernizing America's Energetic Enterprise," (2022).

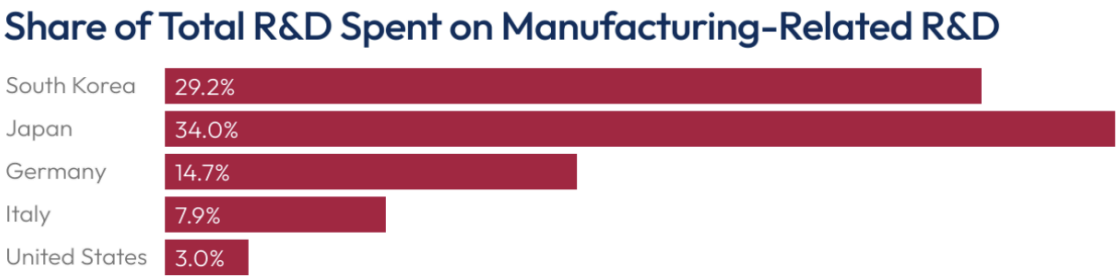
Just as confronting a schoolyard bully's brute force requires building your own strength, standing up to abuse, and teaming up with friends, responding to China's brute force economics demands a comprehensive approach: rebuilding domestic industrial capabilities, countering predatory economics, and forging deeper partnerships with democratic market economies. This three-part strategy is a path to maintaining technological leadership while preserving economic freedom.

Promote

America has finally awakened to the industrial challenge, as shown by the CHIPS and Science Act of 2022. While this experiment in industrial strategy marks a vital shift, we must do far more to accelerate domestic competitiveness. Here are three specific steps to build on this momentum:

- **Finish what we've started:** CHIPS aimed to reverse the decline of domestic U.S. semiconductor fabrication capability and it is already starting to bear fruit. TSMC has begun production of leading-edge 4 nm chips in Arizona, and the CHIPS Act's $52 billion in funding has catalyzed nearly $450 billion in private investment in semiconductors and incentivized the creation of tens of thousands of jobs.[21] We must now ensure rigorous implementation and look beyond today's chips to strategically direct R&D funding toward breakthrough technologies that will secure American leadership in post-silicon computing.[22]
- **Reindustrialize:** Semiconductors are just the start. America needs a comprehensive approach to lead the fusion of AI with physical industry. When only 12% of U.S. factories use advanced robotics, we're not ready for an era where software meets steel. Ninety-eight percent of U.S. manufacturers are small and medium-sized enterprises, and many of them face difficulties financing upgrades and adopting cutting-edge technologies. Moreover, U.S. government support for manufacturing is miniscule compared to other leading manufacturing nations. We need a national action plan that uses targeted government support to unlock private investment and drive widespread technology adoption, enabling efficient, localized, high-mix production.[23]

[21] "Biden-Harris Administration Announces CHIPS Incentives Award with TSMC Arizona to Secure U.S. Leadership in Advanced Semiconductor Technology," Department of Commerce (2024).
[22] For specific recommendations, see Brady Helwig, "National Action Plan for U.S. Advantage in Advanced Compute and Microelectronics," SCSP (2023).
[23] For specific proposals, see Brady Helwig, Addis Goldman et al, "National Action Plan for United States Leadership in Advanced Manufacturing," SCSP (2024).



Graphic Source: National Action Plan for United States Leadership in Advanced Manufacturing," SCSP (2024). Data is from OECD as of 2022.

- **Talent:** The numbers tell the story: there are 600,000 unfilled manufacturing jobs today, a figure projected to rise to 2.1 million by 2030.[24] This talent bottleneck threatens to undermine our entire industrial strategy. We need to accelerate factory automation, modernize high-skilled immigration, and dramatically expand workforce development programs. Without addressing the talent crisis, our investments in technology leadership will fall short.

Pushback

"Promote" alone is insufficient when our rival is a Leninist superstate weaponizing the world's second-largest economy. The PRC has been sprinting since the 1980s and is now overtaking us in critical areas. The United States and its allies must both defend against brute force economics, and buy time to rebuild their own strength.

- **Export controls:** Export controls are an essential tool to maintain U.S. and allied advantage.[25] But they are a speed bump, not a moat, to slow China's progress. The recent release of Chinese AI company DeepSeek's large language model reinforces the case for doing everything we can to strengthen, protect, and leverage U.S. advantages in compute scaling. DeepSeek has made impressive strides in catching up with leading U.S. AI firms, but it did so with access to U.S. advanced semiconductors, some of which only became restricted in October 2023. If enforced, the effect of the restrictions should grow over time, given the enduring importance of computational resources to AI model development.[26] As DeepSeek's CEO Liang Wenfang said, "Money has never been the problem for us. Bans on shipments of advanced chips are the problem."[27]

[24] Ibid.
[25] Matt Pottinger and Dario Amodei, "Trump Can Keep America's AI Advantage," Wall Street Journal (2024).
[26] Dario Amodei, On DeepSeek and Export Controls (2025).
[27] Jordan Schneider et al, "DeepSeek: The Quiet Giant Leading China's AI Race," *China Talk (2024).*

To strengthen the system of export controls, a few steps are required. *First,* the controls must be updated regularly to keep up with the technology they govern. *Second*, export controls only work if they are enforced. Along with a strong enforcement mandate and licensing policies, agencies need modernization and proper resourcing. They should be equipped with AI-enabled agentic systems to help humans monitor trade flows and detect potential violations; they should also work with industry to develop technological solutions to combat smuggling.[28] A whistleblower program, modeled after the SEC's framework, could provide critical intelligence about violations and emerging risks. *Third*, we should accelerate the shift from a blacklist approach (which PRC companies can easily evade) to country-wide controls. This can expand on the process already underway to create a chokepoint coalition with Japan and the Netherlands to restrict PRC access to advanced semiconductor manufacturing equipment.

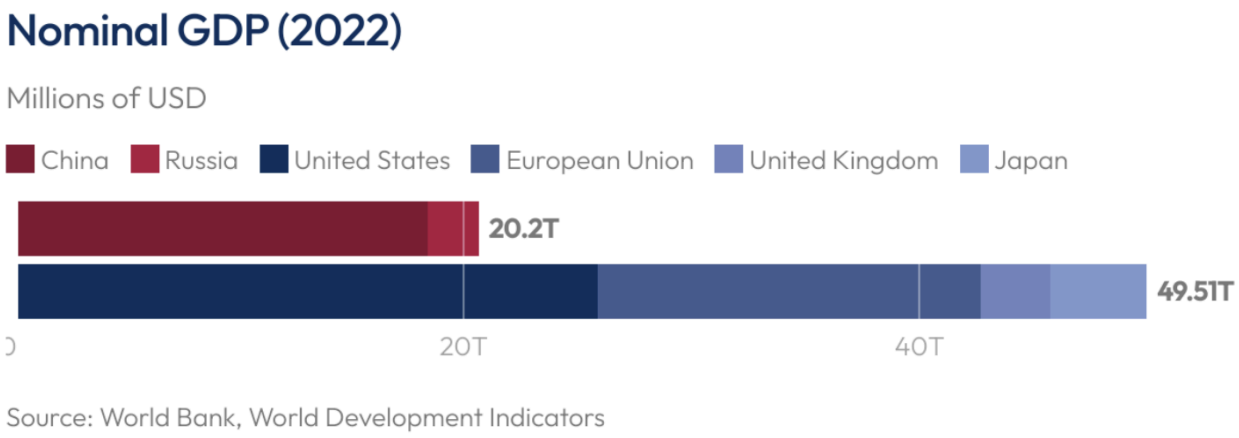
- **Trade Restrictions:** We need smarter trade barriers targeting the world's leading cheater, China. This should include resourcing and stronger enforcement of existing restrictions designed to target egregious behavior by the CCP, such as the Uyghur Forced Labor Protection Act (UFLPA). UFLPA's innovative "rebuttable presumption" principle offers a powerful model that can be applied more broadly in new rules and laws. A potential "presumption of subsidy" principle could be applied to PRC firms in strategic sectors, requiring them to prove they operate without state support before accessing lower trade barriers.[29] Congress should consider codifying the Commerce Department's ICTS authorities (enabling it to restrict imports of internet-connected technologies from adversarial nations) into law, protecting it from potential executive branch reversals in the future. Commerce should consider using ICTS authorities to restrict the import of robotics components and other key components in the manufacturing base. Manufacturing is already the most cyber-attacked sector; digitalization is needed to modernize the sector, but if it is done with components subject to Beijing's control, it will create new vectors of attack.[30]
- **Investment:** Inbound and outbound investment restrictions should be updated to account for China's evolving technology strategy – focusing on sectors where China is investing in, or surpassing, the U.S. but has not yet done so, like biotechnology and humanoid robotics.

Pooling

[28] Onni Aarne, Tim Fist and Caleb Withers, "Secure, Governable Chips," CNAS (2024)
[29] "Memorandum for President-Elect Trump's Transition Team: The Economy," Special Competitive Studies Project (2025)
[30] Additional proposals to strengthen trade protections and cyber-harden the manufacturing base can be found in the National Action Plan for United States Leadership in Advanced Manufacturing," SCSP (2024), on pp. 29-35.

America needs a new vision for trade, one that takes inspiration from the original General Agreement on Tariffs and Trade, the predecessor to the WTO: *free trade for free people, managed trade for autocracies.* While tariffs can play a role, they're just one tool in what must become a comprehensive restructuring of the international economic order.

The WTO has failed to contain China's brute force economics. It's time to build something better: a dual-track system that leverages the combined market power of democracies – more than 60% of global GDP – to overmatch the PRC's ability to weaponize its market. This means preferential treatment for trusted partners who have a track record of fulfilling commitments, while putting strict guardrails around trade with strategic rivals in order to minimize unsafe dependence and blunt PRC economic coercion. Recent initiatives that show promise include G7 coordination on PRC economic coercion, the State Department's Minerals Security Partnership, and the AI Diffusion Rule's three-tiered framework. These efforts need to be expanded.



Conclusion

The U.S. response that has unfolded since 2017 is moving in the right direction but fails to match the scale and sophistication of this challenge. What is required is reimagining how democratic market economies approach economic security: combining robust industrial renewal with modernized trade and technology protections and the creation of a new economic architecture among friendly nations with real markets. In the age of cyber-physical systems, power flows to those who control both code and steel – and nations that excel in software but lack industrial capacity face a bleak strategic reality. A comprehensive response to Beijing's industrial strategy, executed with urgency and precision, can secure America's economic vitality and strategic leadership in the decades ahead.

I would like to thank Pieter Garicano for research and editorial support.

OPENING STATEMENT OF BARRY NAUGHTON, SO KWAN LOK CHAIR OF CHINESE INTERNATIONAL AFFAIRS, SCHOOL OF GLOBAL POLICY AND STRATEGY, UNIVERSITY OF CALIFORNIA SAN DIEGO

VICE CHAIR SCHRIVER: Thank you very much.

Dr. Naughton.

DR. NAUGHTON: Thank you very much, and thank you very much to the Commissioners for allowing me to participate in this hearing virtually. I genuinely appreciate it.

Let me make four basic points. First, I want to endorse the main point made by my fellow panelist that it is really important that we grasp the scale and the multidimensional character of what is happening in China. It really is an unprecedented challenge to the United States, to our industry, to our policy, and ultimately to our national security.

First, within the long-term commitment of China to becoming a manufacturing superpower, we can identify three successive stages of China's industrial policy. The first was something fairly familiar, starting in 2006, going on to about 2015, really targeting sectors where China saw economic opportunity, new growth drivers.

After about 2015, which is right at the time when Made in China 2025 is released, we see China moving very clearly to a second phase of strategy, and that phase is the so-called Innovation-Driven Development Strategy, where Chinese policymakers really take stock of the fact that there is a technological revolution going on, and that China intends to compete at the frontier with the United States for dominance of this. And it lays out, right at the beginning, a geostrategic rationale for this kind of economic policy.

And one of the ways to think about Made in China 2025 is that it represents the Chinese policymakers adapting what had previously been a sort of sectoral targeting approach to this new, across-the-board manufacturing superpower conception based on technological revolution.

That is already very, very important, but then to bring it closer to the present, after 2020, 2021, we see China making a step change towards a new emphasis, not just on competing at the frontier but also at having a self-reliant and self-sufficient industrial system. As Liza stressed, China's manufacturing system is by far the biggest in the world, but that is not enough for Chinese policymakers. They have explicitly said they want to make it less reliant on imports and imported technology in every dimension, while at the same time maintaining the dependency that other countries have on Chinese exports. So in other words, this strategy has clearly shifted to one where self-reliance and geostrategic dominance is at the center of each step of practical policymaking.

Made in China 2025 is still with us. It has been rebranded. It is now called China Manufacturing Superpower. And some of the techniques have shifted a little. Again, it is less sectoral, but there is a set of green books that lay out a wide array of manufacturing sectors, and for each sector identifies the technologies, the materials, and the key components for which China is still dependent on imports. And then there are roadmaps for 2030, 2035.

They have learned their lesson. They don't publish quantitative targets for reducing these dependences, but the clear implications are by 2030, by 2035, or later, we, China, reduces our reliance on imported technologies in these areas.

That has led then to a very important shift in instruments. Up until 2020, China tried very hard to implement its industrial policy with market-conforming instruments. There were many of them. They were overlapping. There were subsidies. There were taxes. There were government guidance funds, which made investments like a venture capital firm. But all these, they tried to

retain the advantages of a market economy matched with a kind of government steerage.

What has happened in the last couple of years is that Chinese policymakers have become too impatient, and they are now increasingly pushing top-down government-organized forums, which they give creative names to. One is "New Style Whole-of-Nation System" for large, central government-organized programs, and another is "Innovation Consortia" that can be organized at the local level or by central government ministries. This involves a government stepping in, serving as a kind of forceful matchmaker to push firms, research institutes, and service providers together into a new government-steered organization.

Final point, all these measures, this increase of priority, definitely creates a very strong challenge for the United States. At the same time, it is important for us recognize that these are extremely economically costly measures for China. Stepping away from the market costs them a lot. Trying to substitute for higher quality, cheaper imported components costs them a lot. Their focus on becoming a manufacturing superpower makes it much more difficult for them to resolve their housing crisis, which they have now been stumbling through for three years. It makes it harder for them to rectify their fiscal system difficulties.

So they are definitely paying a cost for these programs, which reflects their priorities. I think they are more concerned with the geostrategic advantages than they are with the economic costs.

But as we respond to this great challenge it is very important that we don't swing to the opposite extreme, that we maintain our advantages through a selective policy that allows us to benefit from the cost advantages of trade, when we can manage free trade, and also protect certain key industries when we deem them essential for our security.

Thank you. I will stop there.

VICE CHAIR SCHRIVER: Thank you. Dr. Chan.

PREPARED STATEMENT OF BARRY NAUGHTON, SO KWAN LOK CHAIR OF CHINESE INTERNATIONAL AFFAIRS, SCHOOL OF GLOBAL POLICY AND STRATEGY, UNIVERSITY OF CALIFORNIA SAN DIEGO

Testimony USCC

February 6, 2025

Barry J Naughton

So Kwanlok Professor, School of Global Policy and Strategy, University of California, San Diego

Testimony before the U.S.-China Economic and Security Review Commission

Title of Hearing: "Made in China 2025—Who Is Winning?"

Questions

1) **How have the objectives of China's industrial policy shifted in recent years? What factors and drivers are currently shaping the technologies and industries Chinese policymakers are focusing on, and how does this process differ from Made in China 2025?**

China's industrial and innovation policies have significantly changed their objectives over the past twenty-some years. We can clearly identify at least three different stages: (1) Choosing sectors, 2006-2015; (2) Mastering the new technological revolution, 2016-present; and (3) building self-sufficiency, 2020-present. Each of these phases has different characteristics. They have different goals, and also instruments, favored institutional arrangements, and principles of implementation. Each of them envisions a different kind of relationship between government and the market. Yet once one of these policy complexes is set in place, it remains there, and the subsequent phases and objectives are built on top of it. This creates a landscape of enormous complexity as well as an environment of steadily accelerating government commitment to industrial policy.

CHOOSING SECTORS, 2006-2015. Industrial policy in these years was often conceptualized as developing "new growth drivers," and the effort was intensified during the 2009 Global Financial Crisis. The most obvious example is the Strategic Emerging Industries (SEI) program which began in this phase and is still with us. This phase was similar to predecessor industrial policy in Japan and Korea, being largely expressed through the desire to target, nurture, and accelerate the growth and scale-up of specific industries.

The most obvious example of the SEI program has been electric vehicles (EVs). The degree of Chinese policy commitment to the EV and battery sectors was unusual. China has given policy support to EVs for almost twenty years now, and for about sixteen of those years, it was uncertain whether policies would bear fruit. Despite the uncertainty, the government maintained its commitment. Why? This policy consistency was probably due to a convergence of strategic goals: Economically, a new export industry was envisioned to sustain growth, create jobs, and replace labor-intensive exports where China was losing competitiveness. Strategically, they contributed to China's long run effort to reduce its dependency on imported oil. Environmentally, China's severe air pollution problems in major cities reinforced the policy commitment.

With long-term policy commitment, China was willing to try many expensive subsidy programs. There were many missteps and enormous waste, certainly costing tens of billions of dollars over a decade. However, ultimately the willingness to support the sector and the willingness to bear costs from policy experimentation and mistakes led to the creation of a competitive sector.

MASTERING THE NEW TECHNOLOGICAL REVOLUTION, 2016-PRESENT. China's "Innovation-Driven Development Strategy" (IDDS) was formally launched in 2016. This policy marked a clear determination to go beyond promotion of individual sectors and support an entire complex of activities, what I have elsewhere called the "triangle of communication, data, and artificial intelligence." Rather than a specific sector, the IDDS targeted a cluster of inter-related technologies that together formed what economists label a "general purpose technology" (GPT) that transforms every sector in an economy. Such technological revolutions come about less than once a generation.

The IDDS also marked a clear intention to compete with the US at the frontiers of the new technological revolution. It was striking that the IDDS explicitly declared that geostrategic competition was one of the main reasons that China had to master the new technological revolution.

"Made in China 2025" (MIC 2025) was adopted as a policy just as the IDDS was being adopted as a guiding policy document. It represented an effort to bring sectoral policy into harmony with the ambitious strategic aims of the IDDS. While Strategic Emerging Industries had been selected on an individual sector basis, MIC 2025 envisioned making China an overall manufacturing superpower. In pursuit of this goal, quantitative targets for import substitution were (famously) laid out in a supporting document. MIC 2025 represented a melding of different strategic objectives, supporting sector targets as well as goals for general economic upgrading through a new general purpose technology.

BUILDING SELF-SUFFICIENCY, 2020-Present. Self-reliance became an explicit policy objective during the course of 2020. "Science and technology self-reliance and self-strengthening" was written into the 14th Five Year Plan (2021-2025). In terms of industrial policy, a clear shift has been discernable toward identifying and reducing specific "dependencies." That has meant identifying specific technologies, components and materials on which China has relied for imports. The policy of "modernized industrial system," (现代化产业体系) despite its bland name in translation, refers to an ambitious policy to reproduce in China as many of the elements of a modern production system as possible. That includes not just large manufacturing enterprises, but also specialized service providers, niche equipment makers, and all the elements of a robust start-up ecosystem.

One of the motivations in developing this new policy orientation was clearly the heightened tensions between China and the US, and the initiation of a sanctions regime and specific technological embargoes by the US after 2018. Equally, the prospect of withdrawal from China of specialized goods and service providers led Chinese policymakers to strategize developing domestic replacements. The "dual circulation" strategy of this time balanced domestic and foreign "circulation," but the emphasis was clearly on ensuring that domestic economic activity could continue uninterrupted in the case of international economic disruption or foreign sanctions.

During this time period, Chinese policymakers stopped talking about "Made in China 2025," but they continued to refer to the same policy under the rubric of "Manufacturing Superpower" (制造业强国)。 Technology roadmaps have continued to be produced in the spirit of MIC2025. The latest versions are careful not to publicize any quantitative targets but they are, if anything, more detailed in terms of the specific components, materials, and technologies that China needs to master. In this as in other respects, policy is cumulative. While Strategic Emerging Industries and Made in China 2025 have been superseded by other headline slogans and new strategic emphases, they have by no means been abandoned.

2) How has the Party-state used market actors and market forces in pursuit of these objectives? As China's techno-industrial ambitions evolve, is its manipulation of market forces likely to intensify or diminish?

China's economy is a market economy at its base, and private businesses play a predominant role. Policymakers have tried to steer the market towards their objectives, but in the past 3-5 years, policymakers are showing signs of impatience with market forces and have increasingly used direct administrative interventions.

In the first two stages of China's industrial policy, great attention was given to finding market-conforming instruments to "steer" the economy. In the first phase, much attention was given to tax breaks and low interest loans. Direct subsidies to producers were prominent in the first phase of EV promotion, but they were very expensive and not very effective. Later subsidies shifted toward a mixed program of subsidies to consumers and conditional subsidies to seller (meeting certain technical benchmarks). Waste declined and subsidies are currently being phased out.

Perhaps the most ambitious market-conforming instruments were the "government guidance funds" (GGF) introduced in 2014 and expanded dramatically after 2016 (in line with the IDDS). These were structured like a venture capital fund, with a managing "agency" and limited partners (usually, but not always, state-funded). The managing agency had commercial incentives and rewards, and were supposed to have substantial scope for independent decision-making.

However, recently policymakers have been impatient with market-conforming institutions. The biggest GGF, the national semiconductor "big fund" was rocked by corruption allegations a couple years ago, and its managing agency head replaced by a government bureaucrat. Other GGFs have been reined in, and their subservience to government policy requirements re-emphasized. New forms of direct intervention have been introduced (see next item).

What must be stressed is that many of China's industrial successes can be traced more directly to a strong market environment and entrepreneurial culture than to industrial policy. The electric vehicle industry grew out of a dense network of local battery and component producers. They produced cost-effective solutions, sometimes at a lower technological level, that contributed to downstream producers. Of course, BYD, China's EV champion, also benefited from an infusion of international talent through its cooperation with strategic investor Warren Buffet. More recently, DeepSeek's success in AI large language models came through an independent private firm (investment company, in this case) operating with commercial and individual motives. In all these cases, though, Chinese policy played an important role in investing in human resources and assuring a stable supportive policy environment. However, the main impetus for the actual technological solutions came from private entrepreneurs.

3) **What policy instruments have Chinese policymakers developed and deployed to advance China's techno-industrial objectives? How effective have these instruments been?**

In the last 3-4 years, the Chinese government has increased its reliance on direct interventions. The "new-style whole-of-nation system" has seen government-led organization of research groups targeted at key technological challenges. "Innovation consortia" organized both at the central and local government levels bring together research institutes (or universities), engineering firms and specialized suppliers, and final product companies. The objective is to organize the entire "innovation chain," with top-down guidance pushing firms into collaborative relationships they might not have chosen on their own.

These more aggressive forms of government guidance are relatively new, and we have not had the opportunity to assess their effectiveness. It seems likely that this type of intervention will be less efficient and will result in substantial waste. However, this more aggressive approach corresponds with a continuing increase in the level of government attention and volume of government resources. Thus, China is throwing more money at its technological objectives, while paying the cost of lower efficiency. It is not an accident that these aggressive institutional interventions have come at the same time that China has committed to trying to recreate domestically an entire semiconductor manufacturing industry. This is an extraordinarily costly, difficult, long-term endeavor. Whether or not it succeeds, it will inevitably commit the Chinese government to an extraordinary long-term commitment, and the Chinese economy to a corresponding long-term burden.

4) **What were the market-based and/or policy environment differences between areas where China's policies have been effective and those where they have been less effective?**

It is striking that China's biggest successes have come in industrial sectors where entry barriers are not particularly high, and where a diverse and competitive seedbed of enterprises provides numerous candidates for success. When this exists, government policy support seems to be especially effective. This clearly characterizes China's battery, solar panel, and electric vehicle industries.

Alternately stated, Chinese firms have a demonstrated record of success in scaling up production rapidly once they have managed to survive the risky start-up stages. At its most successful, Chinese industrial policy creates a short-term protected environment that welcomes audacious entrepreneurs. Subsequently, the market and policy environment creates a tournament, where only the fastest moving businesses can survive. This impels a frantic race to become established and reach economic scale. Such an environment has obvious costs: excess capacity is created; many firms lose money; and government usually intervenes to facilitate takeover of less successful firms by the winners. The Chinese government unsurprisingly seeks to dilute those costs by dumping some of these low-price goods—potentially priced below cost—on the world market. However, from their standpoint, once a few firms manage to rise out of the competitive bloodbath, they are established as "national champions." Strikingly, the practical skills learned in this phase of vicious competition seem to translate into the next phase of expansion. The best Chinese firms have managed to scale up continuously after establishment. Following the well-known "experience curve," unit costs have continued to decline for an extended period as

cumulative production grows. This experience has been very much in evidence with China's solar panel producers, and with China's electric vehicle champion, BYD.

Conversely, Chinese policy has been much less successful in those areas where small-scale and dispersed entry is not technologically possible, and it falls to government or state-sponsored businesses to create new firms. This describes China's semiconductor industry, where China has repeatedly failed to create new national champions at scale. Creation of a state of the art semiconductor fab requires the simultaneous installation of an extraordinary range of equipment and the precise coordination of many different kinds of activity. "Learning by doing" and various kinds of tacit knowledge are essential. China does not generally have the extraordinarily detailed management and coordination capabilities necessary to pull this off. There may, however, be exceptions in some of the state-run, high-priority sectors such as China's space program. China seems to have experienced an extraordinary run of space program successes in recent years, hitting most of its long-range targets more-or-less on schedule. However, this program, like all programs directly or indirectly related to the military, is shrouded in secrecy, so it is difficult to be confident about any generalizations.

5) What are the drivers behind the reorganization of China's science and technology system launched in 2023, and how will the centralization of science and technology policy through the establishment of the Central Science and Technology Commission affect China's approach to innovation?

The reorganization of China's S&T system in 2023 is clearly a part of the increased priority given to technology self-sufficiency and the increased recourse to direct administrative interventions that follow on the post-2020 emphasis on technological self-sufficiency. The Central Science and Technology Commission is a Communist Party body designed to give the highest political priority to science and technology measures. It is headed by Ding Xuexiang, who is very close to Xi Jinping. In addition, Premier Li Qiang has been extremely active in publicly advocating for central government technology policy in visits around the country. There is no question that the Commission directly organizes the "new-style whole-of-nation" projects run by the central government and supervises the "innovation consortia" run by both central and local governments. These measures inevitably undermine the overall entrepreneurial environment in China, even as they lead to greater flow of resources to high-technology industry.

There is little evidence that this administrative set-up is transforming the policy landscape. The Ministry of Science and Technology (MOST) is tasked with staffing the Central Commission, but MOST is a relatively weak ministry that has recently been stripped of some of its powers. The activities of the Central Commission in directly organizing government projects are doubtless significant, but also invisible to outside observers. For example, China has recently been tracked making significant investments in fusion energy, including both basic and applied research. This is undoubtedly linked to the Central Commission, but we do not know the exact processes. Local government activity in organizing innovation consortia does not seem at all coordinated, and even appears disjointed and duplicative in some cases. It is unlikely that China has achieved a higher degree of centralization in the management of science and technology.

Indirect evidence to support this assertion comes from the role of the Huawei corporation. A number of research press and analyst reports have shown that Huawei has taken a leading role in many stages of the semiconductor production chain. In stages from chip design to specialty component production to equipment manufacturing, Huawei provides capital, management

skills, and technological expertise to other companies. It is inconceivable that Huawei is doing this without government permission and support. Its capacity to do this is a testament to the extraordinary capabilities of this company. However, it also indirectly shows that the Chinese government does not have the capacity to do this on its own, and chooses rather to work through this company.

6) The Commission is mandated to make policy recommendations to Congress based on its hearings and other research. What recommendations not already covered in answer to questions above for legislative or administrative action would you make in this area?

The US should take a balanced view of China's achievements and shortcomings. China has many advantages in the development of industrial technology: it has abundant cheap human resources, resulting from massive investment in human capital, including large-scale study abroad funded by households; a huge domestic market that serves as a lead market for many new technologies; and a large, comprehensive industrial base with abundant opportunities for technological spillovers. These basic facts mean that China is today a major player in industrial technology and will be for the foreseeable future. This will be true no matter what the US does.

At the same time, China's statist model imposes huge costs on the Chinese economy and the Chinese people. China is pouring resources into the development of a self-sufficient economy. This implies not only massive waste of resources today, but the creation of an economy that runs with lower productivity in the foreseeable future. The inability of Chinese policymakers today to devise an effective macroeconomic policy; to resolve the housing crisis; and to restructure their fiscal system are all related to the massive over-investment in industrial technology.

In this context our primary tasks are to:

1. Ensure that the US prevails in the competition over critical frontier technologies essential to our national security. China presents a serious antagonistic challenge, and we must continue to invest and improve our competitive position in a limited number of critical technologies.
2. Refrain from imposing unnecessary costs on our economy by trying to do everything ourselves (which would simply mean replicating the Chinese policy error). We can continue to trade with other countries, including China, when that enables us to access cheaper inputs and final goods. This makes the US economy more competitive and more able to prevail in the long run.
3. In some specific sectors where Chinese firms have achieved cost breakthroughs, and where there are no immediate security concerns, we should encourage those firms to invest in greenfield plants in the United States. A good example would be photovoltaic panels. There are no technological or scientific secrets involved in the production of solar panels, and we can benefit from the engineering knowhow and practical skills achieved by Chinese firms in this area if they invest in the US.

OPENING STATEMENT OF KYLE CHAN, POSTDOCTORAL RESEARCH ASSOCIATE, PRINCETON UNIVERSITY

DR. CHAN: Thank you for inviting me to testify on this important topic.

China pursues an all-of-the-above approach to achieving global industrial leadership. China's industrial policy does not merely consist of tariffs and subsidies. It is broader, deeper, and more sophisticated than many realize, spanning a vast array of policy tools and actors. These include state bank loans, state-run research centers, local government support for infrastructure and land acquisition, talent poaching, industrial espionage, and a lot more.

Let me highlight three key features of China's industrial policy.

First, China proactively brings in and uses foreign firms to acquire technology. Foreign companies that wish to do business in China are often required to set up not only factories but also R&D facilities in China, and in many cases through joint ventures with Chinese companies. Foreign firms enter into a Faustian bargain, where they profit from selling to China's market in the near term but build up their future Chinese competitors in the long run.

This is what happened with high-speed rail technology. International train makers, like Siemens and Alstom, were eager to take part in what China promised to be a once-in-a-century market opportunity. Rather than simply importing foreign bullet trains, China's Ministry of Railways arranged joint venture between Chinese companies and foreign train makers to build trains in China and share technology and knowhow. Over time, China developed what it claimed to be its own Chinese-designed train models, and merged its train companies into a single, state-owned giant that is now the largest global player in the industry.

China also uses foreign firms to turbocharge its own domestic industry. Apple is one example. Over the years, China has pushed Apple to localize its supply chain and develop China's domestic manufacturing ecosystem. Chinese firms like BOE and Lens Technology have been steadily replacing many of Apple's non-Chinese suppliers. Apple even sends engineers to share production techniques with Chinese firms. Today, many of these same Chinese firms supply components to Chinese smartphone makers, like Vivo, Xiaomi, and Huawei.

Tesla is another example. As it prepared to launch its Shanghai plant, Tesla worked closely with a Chinese-owned equipment maker to develop a massive metal casting machine that it dubbed the "giga press." These powerful new machines helped to revolutionize auto manufacturing by cutting down on time and costs. These "giga presses" were soon adopted by Chinese electric car companies, enabling them to make cars faster and more cheaply than their industry peers.

Although China's EV industry was already expanding rapidly before Tesla's arrival, the launch of Tesla's Shanghai plant helped to turbocharge its growth and train a whole generation of Chinese engineers and technicians in new production techniques.

A second key feature of China's industrial policy is its remarkable adaptability. Rather than giving up in the face of setbacks or challenges, China frequently shifts strategies, testing to see what works and doubling down where it finds success. For example, China's auto industry was once seen as an industrial policy failure. Years of joint ventures with foreign automakers failed to make Chinese car companies competitive or innovative.

So China tried to leapfrog the industry altogether with electric vehicles. China threw the kitchen sink at the problem, investing in a range of technologies, rolling out subsidies and tax breaks, and tilting the playing field heavily in favor of domestic firms over foreign ones.

A lot happened at the local level, where city governments bought fleets of public buses

that were electric, created EV exemptions for traffic restrictions, and built up charging infrastructure. Private companies, like CATL and BYD, received significant state support.

The success of China's EV industry today is but the latest phase in a long process of trial and error. We see similar policy pivots in China's semiconductor industry. China has tried backing a variety of partnerships with foreign companies. China has launched giant state investment funds that have led to bankruptcies and fraud, but also some success. In the face of export controls from the U.S., China has explored tactical workarounds, like advanced packaging, and pushed companies to buy domestic chips. DeepSeek's recent breakthroughs in AI are already being used to improve performance of Huawei's AI chips.

A third key feature of China's industrial policy is that it seeks to develop Chinese firms that can compete globally. While China has long pursued an export-led growth strategy, what is different this time is that Chinese firms are now competing in high-value, high-tech industries that were once dominated by the U.S., Europe, and Japan.

China doesn't just make solar panels. It makes the manufacturing equipment that makes solar panels. China doesn't just make electric cars. It makes their core components, from batteries to electric motors. It even makes the industrial robots that make the cars.

Chinese firms trying to expand globally have been met with a range of responses. Some countries, like the U.S., have sought to limit Chinese products like EVs, through tariffs or national security rules. Other countries or regions, like the EU, Brazil, and Turkey, have placed tariffs on Chinese imports while welcoming some forms of Chinese investment. Beijing has taken a tailored approach, encouraging Chinese firms to build factors in friendly countries and holding back investment in others.

China's determined efforts to lead the world in a range of critical high-tech industries poses a distinct challenge to the United States. The conventional view of international market competition no longer applies. In a growing number of industries, the United States faces a binary choice -- compete intensively or let China dominate.

In strategic sectors where the U.S. is dominant or competitive, we should provide policy support to prevent our industries from going under, especially in the face of market volatility. We should also limit the ability of American companies to set up manufacturing and R&D facilities in China when it might result in technology transfer or even for outdated technology.

In sectors where we lag behind, like EVs and batteries, we should use industrial policy tools to develop our manufacturing base and acquire technology from industry leaders. This includes turning China's industrial playbook back on itself, and using access to our market to get technology from Chinese firms.

Ultimately, we must do more to actively support our industries and stay ahead in the intensifying race with China. Thank you.

PREPATED STATEMENT OF KYLE CHAN, POSTDOCTORAL RESEARCH ASSOCIATE, PRINCETON UNIVERSITY

Testimony before the U.S.-China Economic and Security Review Commission

Hearing on "Made in China 2025—Who Is Winning?"

February 6, 2025

Kyle Chan

Postdoctoral Research Associate
Department of Sociology, Princeton University

Vice Chair Schriver, Commissioner Kuiken, members of the Commission, and Commission staff, thank you for inviting me to testify on Made in China 2025 and China's industrial policy.

China today dominates a wide range of industries, both traditional and emerging, from steel and shipbuilding to lithium batteries and electric vehicles. China has succeeded or made significant progress in most of the target sectors set out in the original Made in China 2025 program, including telecommunications equipment, industrial robotics, high-speed rail, and clean energy. In 2023, China was the largest net exporter of manufactured goods, which exceeded $1.8 trillion in value.[1] The United Nations projects China's share of global industrial production will reach 45 percent by 2030.[2] Chinese President Xi Jinping has repeatedly called for China to become a "manufacturing powerhouse" (制造强国), a term that was used throughout the original Made in China 2025 document.[3]

China pursues an all-of-the-above approach to achieving global industrial leadership. China's industrial policy does not merely consist of tariffs and subsidies. It is wider, deeper, and more sophisticated than many realize. China uses an exceptionally broad array of policy tools and strategies to acquire technology and build up its industrial capacity. These include steep protectionist barriers, joint ventures with foreign firms, state bank loans, industrial espionage, talent poaching, support with land acquisition and infrastructure, resource deals with foreign governments, and strategic outbound investments, to name a few. These are not passive, static tools but rather active policy efforts, often involving coordination or direct intervention by state organizations.

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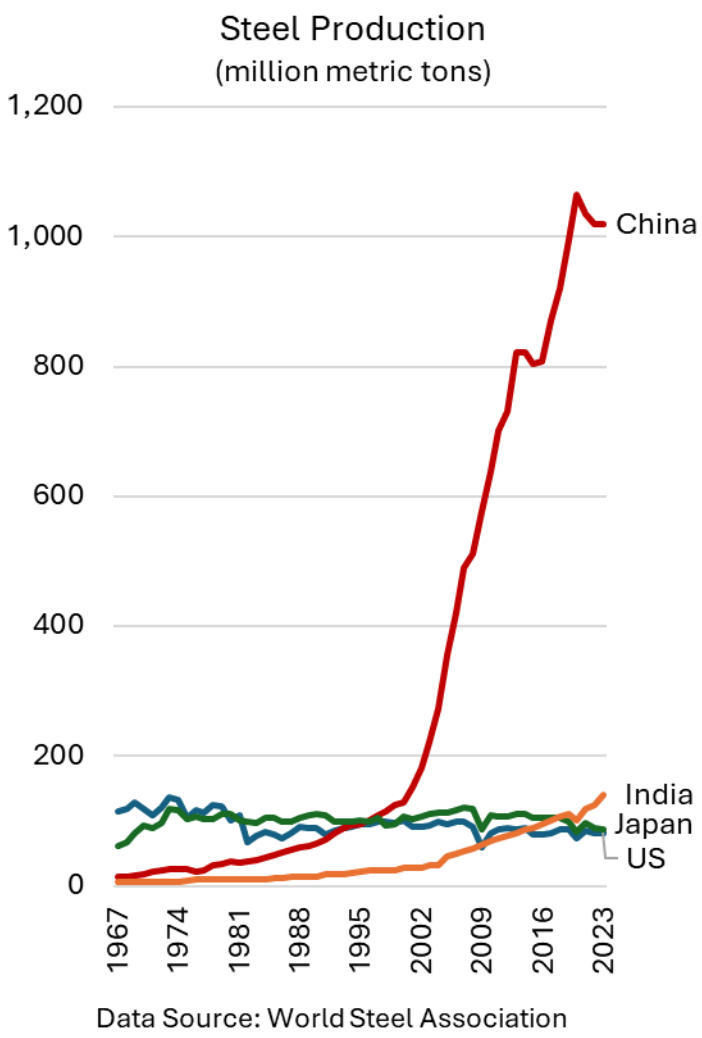
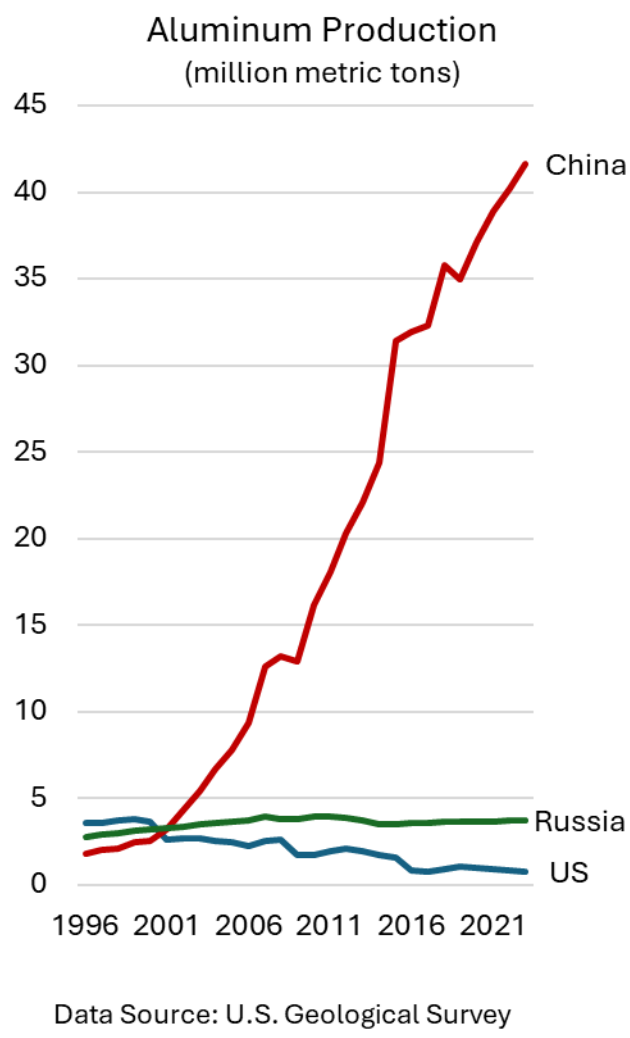
[1] Brian Hart, Hugh Grant-Chapman, and Leon Li, "China dominates global manufacturing," Center for Strategic and International Studies, https://www.csis.org/analysis/china-dominates-global-manufacturing.
[2] UN Industrial Development Organization, *The Future of Industrialization*, 2024.
[3] PRC State Council, "Made in China 2025 (中国制造 2025)," May 8, 2015, https://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm



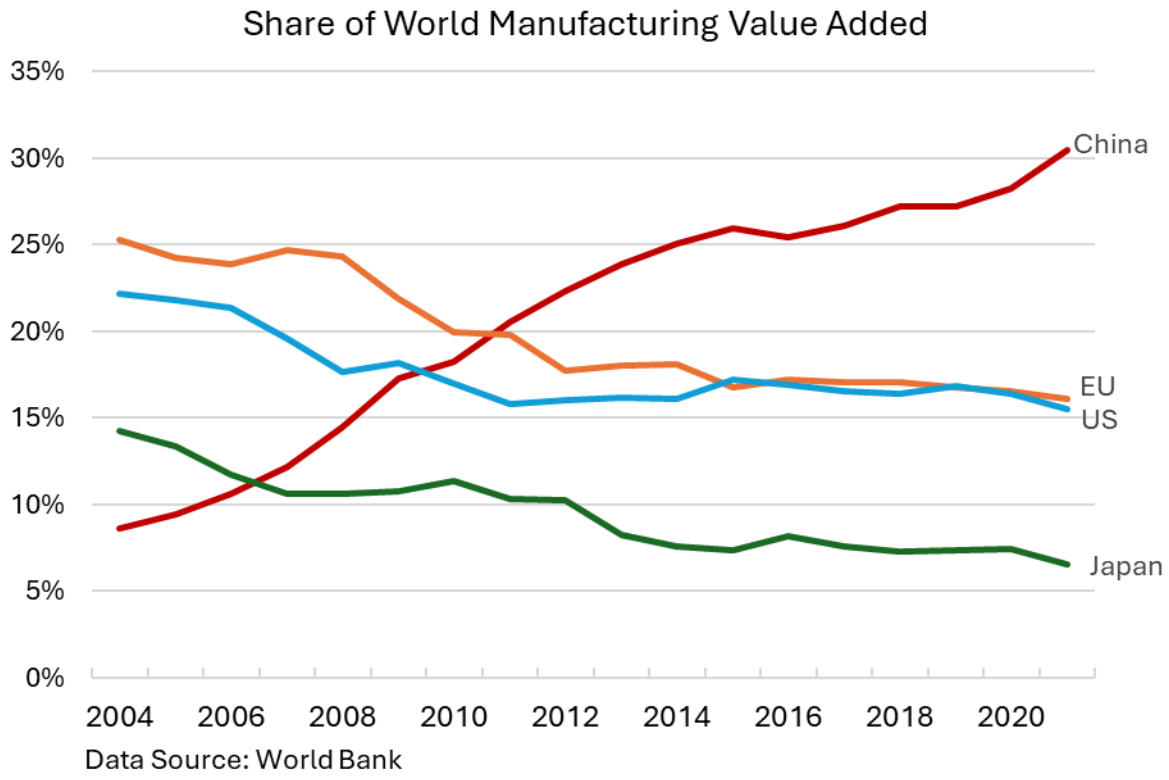
Data Source: World Steel Association



Data Source: U.S. Geological Survey

China's industrial policy also involves a sprawling constellation of state and private entities, including state-owned enterprises, state-run research centers, universities, industry associations, local government financing vehicles, venture capital firms, startups, and partnerships with foreign firms and universities. State efforts to support Chinese firms often span across multiple levels of government, from local government departments and bureaus to central ministries and commissions. In some cases, the central government takes the lead, often laying out an industrial policy agenda like Made in China 2025 to signal to local governments, firms, and other actors where they should direct their resources. In other cases, competition among local governments can produce ground-up policy innovations that are later incorporated into nationwide initiatives.

This testimony will highlight three features of China's industrial policy that make it particularly distinctive and effective.

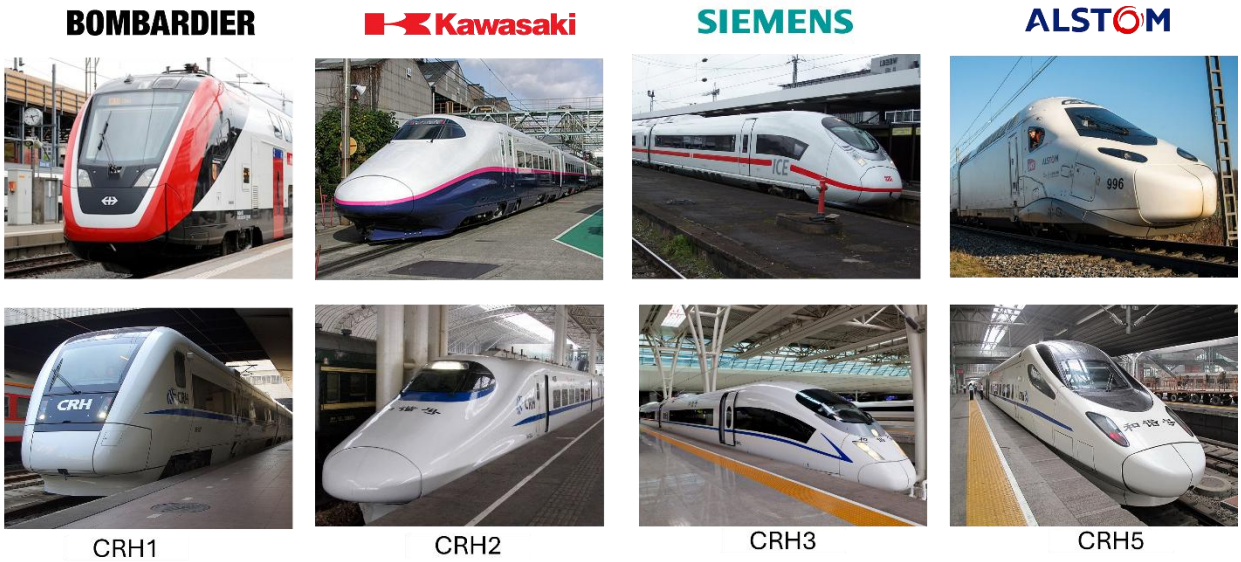


1. Foreign Technology Acquisition

A central component of China's industrial policy has been the acquisition of foreign technology through joint ventures and other partnerships with foreign firms. Across a range of industries, China has required foreign firms that wish to sell to the Chinese market to establish manufacturing facilities in China, often through joint ventures with Chinese firms. This strategy even has a name in Chinese—市场换技术—that translates to "market access in exchange for technology." In addition to joint manufacturing facilities, Beijing also presses foreign firms to establish R&D centers in China, helping to share cutting-edge technology and train Chinese scientists and engineers. Ultimately, foreign firms agree to a Faustian bargain where they profit from selling to China's market in the near term but build up their future Chinese competitors in the long run.

China's high-speed rail industry provides a striking example of China's use of joint ventures to acquire foreign technology. In the early days of China's high-speed rail program, China's Ministry of Railways directly arranged joint venture partnerships between foreign high-speed train makers, such as Siemens and Alstom, and Chinese train makers, such as Changchun Railway Vehicles and Qingdao Sifang.[4] China promised foreign train makers access to a once-in-

[4] Chen Wang, "An all-powerful owner is born (全能业主诞生)," Caixin, July 2, 2012, http://magazine.caixin.com/2012/cw508/.

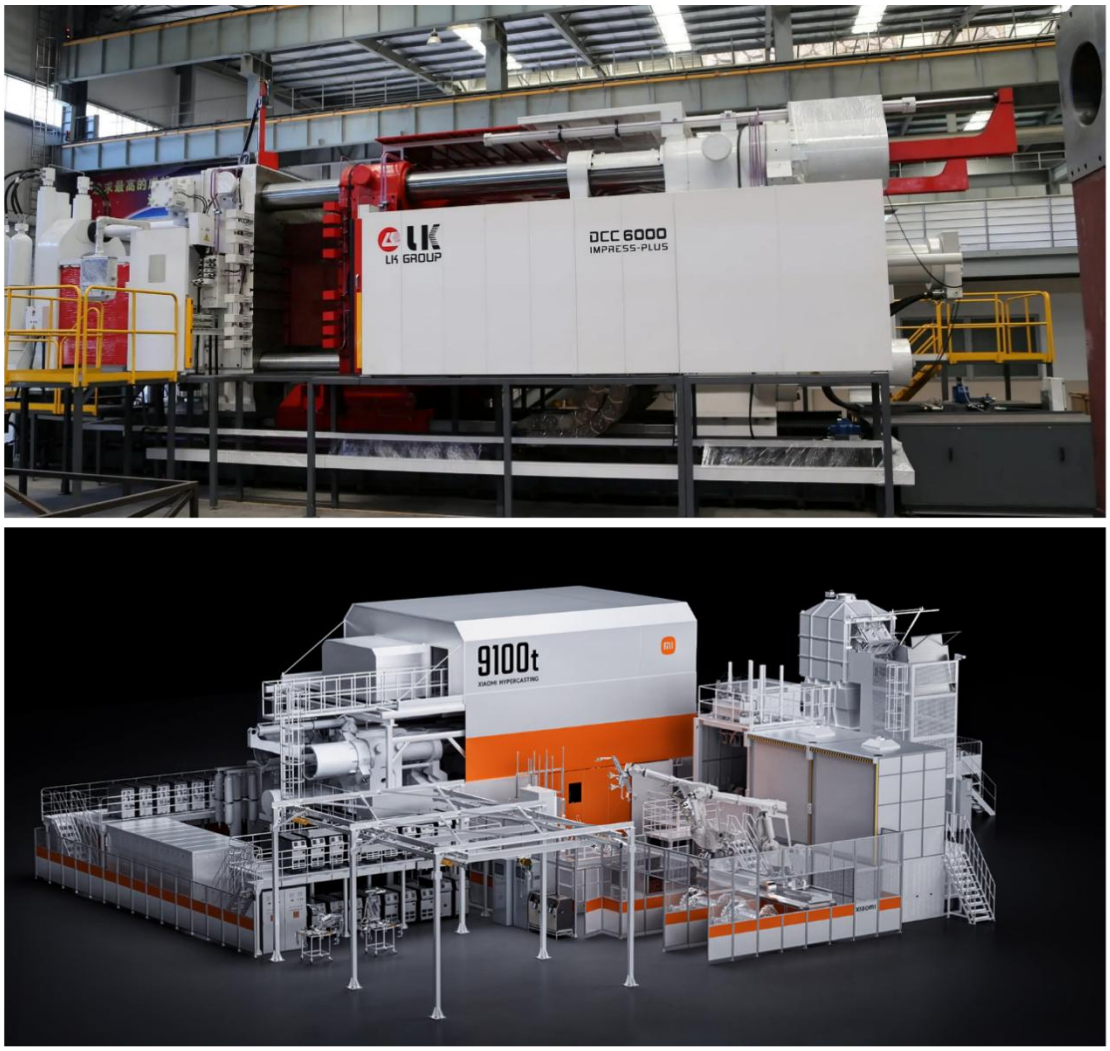


Chinese high-speed train models manufactured through joint ventures with foreign train makers

a-century market in exchange for sharing high-speed train technology and manufacturing know-how with Chinese firms. In the years since, China merged its train makers into a single state-run giant, CRRC, and developed what it claims as its own "indigenously" designed and manufactured high-speed train models. CRRC has now become the top global competitor to its former Western and Japanese partners and was cited as a reason for Siemens and Alstom to merge their train manufacturing businesses.[5]

Another example is China's auto industry. For decades, China had required foreign automakers to establish joint ventures with Chinese state-owned firms. What began with a single joint venture between Beijing Auto and American Motors Corporation in 1984 expanded into over 70 joint ventures and another 500-plus joint ventures in auto parts manufacturing by 2000.[6] GM, Ford, Volkswagen, Renault, Toyota, Honda, Hyundai—virtually every major international automaker formed joint ventures with Chinese firms to produce cars for China's growing auto market. In 2007, GM's CEO at the time said of his company's joint ventures in China: "We made a big bet back in 1997, and it's paid off for us very well."[7] Indeed, foreign automakers such as GM and Volkswagen made billions of dollars in profit from selling to China's booming auto market during this period. However, through this process, foreign automakers shared technical designs, manufacturing processes, and supply chain management techniques with their Chinese

[5] Alexander Hübner and Cyril Altmeyer, "Alstom, Siemens to merge rail businesses to counter China's CRRC," Reuters, September 27, 2017, https://www.reuters.com/article/world/alstom-siemens-to-merge-rail-businesses-to-counter-chinas-crrc-idUSKCN1C118P/.
[6] Kaidong Feng, "Chinese indigenous innovation in the car sector: being integrated or being the integrator," Yu Zhou, William Lazonick, and Yifei Sun (eds.), *China as an Innovation Nation*, Oxford University Press, 2016.
[7] Gordon Fairclough, "GM's Chinese partner looms as a new rival," The Wall Street Journal, April 20, 2007, https://www.wsj.com/articles/SB117700975798475867.



Above: LK Group gigapress. Source: LK Group. Below: Xioami hypercasting machine. Source: Xiaomi

partners. In 1995, GM even sold its rare earths magnet division to a consortium that included Chinese partners that would later sow the seeds for China's future EV industry.[8]

In some cases, China brings in global industry leaders to "turbocharge" its own domestic industry. One example is Tesla. In 2018, Tesla CEO Elon Musk struck a deal with the government of Shanghai led by then-party secretary Li Qiang (now China's premier) to build a Tesla plant. The Shanghai government pressed Tesla to work with Chinese suppliers and develop China's electric vehicle manufacturing ecosystem. As part of this process, Tesla worked with China's LK Group and its Italian subsidiary Idra Group to develop a massive industrial casting machine used to make large aluminum auto parts. Tesla named this machine the "giga press."[9]

[8] Ernest Scheyder, *The War Below: Lithium, Copper, and the Global Battle to Power Our Lives*, 2024, Simon & Schuster, p.109.
[9] Li Yuan, "In China, Tesla Is a Catfish, and Turns Auto Companies Into Sharks," The New York Times, November 30, 2021, https://www.nytimes.com/2021/11/30/business/china-tesla-electric-cars.html.

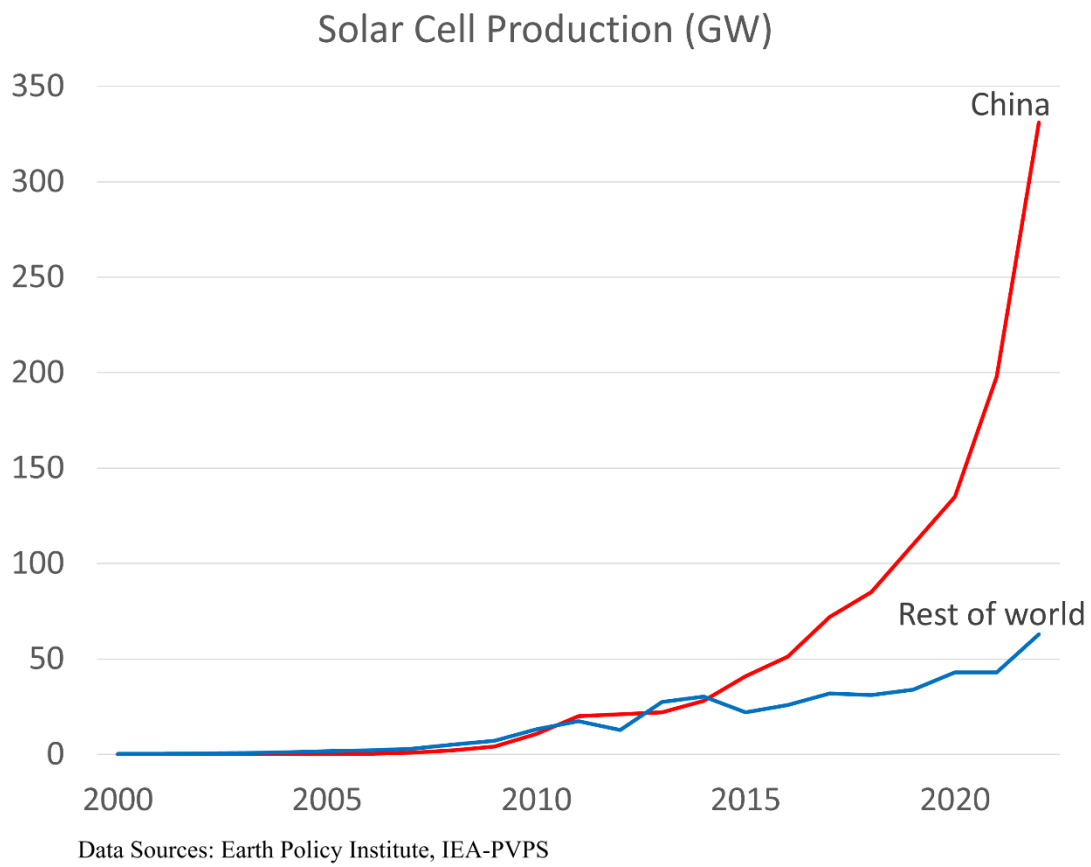
This innovation in auto manufacturing significantly reduced the costs and time required to produce key components. Chinese electric car companies quickly adopted similar "giga presses," including ones made by LK Group, for their auto plants, enabling them to produce cars faster and more cheaply than their industry peers. In addition, China pressures foreign firms like Tesla to localize their supply chains within China. In 2022, a Tesla China executive announced that Tesla's Shanghai plant had localized over 95 percent of its supply chain.[10] Through its Shanghai plant, Tesla has now trained a whole generation of Chinese managers, engineers, and technicians in its manufacturing and supply chain management techniques.

China has also used Apple to build up its smartphone and consumer electronics industry. To convince Apple and its Taiwanese contract manufacturer Foxconn to build their original iPhone factory in Zhengzhou, the city government provided a full-spectrum package of incentives that included tax breaks, loans, support for factory and housing construction, and even worker recruitment and training support.[11] Since then, Beijing has pushed Apple to help develop Chinese suppliers and localize component manufacturing. In some cases, Apple engineers work directly with Chinese suppliers such as BOE and Lens Technology to share new manufacturing techniques.[12] Of Apple's 187 suppliers, 87 percent have production facilities in China.[13] Chinese firms are increasingly supplying iPhone parts, such as camera modules, touchscreen displays, and titanium frames. Chinese state-backed NAND chip maker YMTC nearly won a contract to supply Apple with memory chips before the U.S. intervened to block the move.[14] Many of these same Chinese component manufacturers are now suppliers to Chinese smartphone companies, such as Vivo and Oppo, which are challenging Apple and Samsung in international markets.

2. Adaptability

Another key feature of China's industrial policy is its adaptability. China has repeatedly demonstrated an ability to adjust or even dramatically reorient its industrial strategy in response to unforeseen challenges or opportunities. For any given industry, China often employs not one but multiple strategies simultaneously, testing to see what works and then quickly doubling down on ones that appear to be gaining traction. This process of trial and error is frequently wasteful and inefficient, leading to many policy dead ends and unsuccessful business ventures. However, from Beijing's point of view, these efforts are ultimately justified by China's overall progress in driving industrial upgrading and economic development. Crucially, China's industrial policy

[10] Phate Zhang, "Tesla VP says over 95% of Giga Shanghai's parts come from local suppliers," CnEVPost, https://cnevpost.com/2022/08/15/95-tesla-giga-shanghai-parts-from-local-suppliers/.
[11] David Barboza, "How China built 'iPhone City' with billions in perks for Apple's partner," The New York Times, December 29, 2016, https://www.nytimes.com/2016/12/29/technology/apple-iphone-china-foxconn.html.
[12] Wayne Ma, "How Apple boosts Chinese suppliers with know-how from foreign companies," The Information, May 3, 2024, https://www.theinformation.com/articles/how-apple-boosts-chinese-suppliers-with-know-how-from-foreign-companies.
[13] Cheng Ting-fang and Lauly Li, "Apple moves closer to China despite supply chain shifts," Nikkei Asia, April 26, 2024, https://asia.nikkei.com/Business/Business-Spotlight/Apple-moves-closer-to-China-despite-supply-chain-shifts.
[14] Cheng Ting-fang, Lauly Li, and Yifan Yu, "Apple freezes plan to use China's YMTC chips amid political pressure," Nikkei Asia, October 17, 2022, https://asia.nikkei.com/Business/Tech/Semiconductors/Apple-freezes-plan-to-use-China-s-YMTC-chips-amid-political-pressure



Data Sources: Earth Policy Institute, IEA-PVPS

often remains doggedly persistent in pursuing its overarching goals over the long run, changing strategies rather than giving up in the face of setbacks.

China's solar industry offers an example of how China alters its strategy in response to changes in the international economic environment. In the 1990s, Germany and several other European countries launched ambitious renewable energy policies that provided significant subsidies for solar power. At the same time, solar cell and module equipment makers in Germany, Japan, the U.S., and elsewhere began to sell comprehensive "turnkey" solar manufacturing equipment packages that came with technical support teams.[15] Chinese solar firms such as Yingli and Suntech, supported by their local governments, seized on this new opportunity and quickly ramped up solar equipment production to sell to these lucrative markets.[16] This external market opportunity suddenly vanished when European countries pulled back their renewable energy policies following the 2008 global financial crisis. Not long after, the U.S. and E.U. began to place tariffs on Chinese solar imports. Rather than let its solar industry languish, China's central government stepped in with a wave of state bank loans, particularly from China Development

[15] Gregory Nemet, *How Solar Energy Became Cheap: A Model for Low-Carbon Innovation*, Routledge, 2019.
[16] Fang Zhang and Kelly Sims Gallagher, "Innovation and technology transfer through global value chains: evidence from China's PV industry," Energy Policy, 2016.

BYD electric car factory. Source: BYD

Bank, and massive new demand-side policies aimed at dramatically expanding China's own solar energy production.[17]

China's traditional auto industry offers an example of industrial strategy changes in the face of internal industry roadblocks. China's original automotive industrial policy, stretching back to the 1950s, sought to develop a set of state-run automakers with Soviet technical assistance. However, this strategy yielded very low production volumes due to outdated manufacturing techniques. Starting in the 1980s and 1990s, China began to establish joint ventures with foreign automakers to acquire modern technology and manufacturing know-how, as described earlier. In 1994, the State Planning Commission formalized this strategy as China's official automotive industrial policy.[18] While this strategy was successful in boosting China's production volumes, it was widely criticized as a failure for enriching foreign automakers without fostering independent Chinese brands.[19] Starting in the late 1990s, a new generation of Chinese automakers backed by local governments, such Geely and Chery, entered the industry. China's central government initially regarded these upstart firms as "unauthorized" but then gradually threw its support

[17] Matthew Hopkins and Yin Li, "The rise of the Chinese solar photovoltaic industry: firms, governments, and global competition," in Yu Zhou, William Lazonick, and Yifei Sun (eds), *China as an Innovation Nation*, Oxford University Press, 2016.
[18] Eric Thun, *Changing Lanes in China: Foreign Direct Investment, Local Governments, and Auto Sector Development*," Cambridge University Press, 2005, p.55.
[19] An'ding Li, "The debate over 'market access in exchange for technology' in China's automotive industry emerges from the issue of indigenous innovation (中国汽车业"市场换技术"争论折射出自主创新话题)," Xinhua News, February 16, 2006, https://www.gov.cn/jrzg/2006-02/16/content_200705.htm.

behind these new players, which injected a new level of technological and commercial dynamism into a previously slow-moving industry.[20]

China's electric vehicle industry offers an example of a multi-pronged strategy that itself emerged to address failures in China's traditional auto industrial policy. In 2007, Wan Gang, China's new Minister of Science and Technology and a former Audi engineer, led a campaign to develop China's electric vehicle industry and leapfrog over global auto industry incumbents. China pursued multiple technologies simultaneously, including battery-powered electric vehicles, hybrid drivetrains, and vehicles powered by fuel cells. Consumer subsidies and public procurement programs, particularly for bus and taxi fleets, were implemented to generate demand for electric vehicles.[21] License plate-based driving restrictions in large cities such as Beijing and Shanghai designed to reduce air pollution and traffic congestion gave valuable exemptions for electric vehicles. Regulations and subsidies supported the development of EV charging infrastructure.[22] All of this built on significant public and private research and development spending, particularly on battery technology.[23] China's rapid success in EVs and hybrid vehicles, which now make up more than half of new car purchases in China, far surpassed even recent projections by Chinese policymakers.[24]

China's industrial policy has also adapted to external restrictions on China's access to cutting-edge technology, as exemplified by its semiconductor and AI sectors. For decades, China has tried a range of strategies to develop its semiconductor industry. This includes joint ventures with industry leaders, such as Huahong's partnership with NEC, and efforts to poach top talent from foreign competitors, such as SMIC's recruitment of TSMC engineers.[25] Starting in 2014 a year before the launch of Made in China 2025, China began pouring money into the industry through several waves of state-backed semiconductor investment funds. After a series of high-profile industry bankruptcies, including major fraud cases, China's National Development and Reform Commission tried to rein in what it called a "chaotic" industry.[26] More recently, in the face of U.S.-led restrictions on high-end semiconductor chips and manufacturing equipment, China has tried to pursue workaround strategies, including creative uses of deep ultraviolet (DUV)

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[20] Kaidong Feng and Junran Li, "Challenges in reshaping the sectoral innovation system of the Chinese automobile industry," in Kung-Chung Liu, Uday Racherla (eds.) *Innovation, Economic Development, and Intellectual Property in India and China*, Springer, 2019.

[21] Xiaolei Zhao et al, "Policy incentives and electric vehicle adoption in China: from a perspective of policy mixes," Transportation Research Part A, 2024.

[22] Alexandre Gomes, Robert Pauls, and Tobias ten Brink, "Industrial policy and the creation of the electric vehicles market in China: demand structure, sectoral complementarities, and policy coordination," Cambridge Journal of Economics, 2023.

[23] Yang Andrew Wu et al, "A review of evolutionary policy incentives for sustainable development of electric vehicles in China: strategic implications," Energy Policy, 2021.

[24] PRC State Council, "Notice regarding the new energy vehicle production development plan (2021-2035) issued by the State Council's General Office (国务院办公厅关于印发新能源汽车产业发展规划（2021—2035 年）的通知)," October 20, 2020, https://www.gov.cn/zhengce/content/2020-11/02/content_5556716.htm.

[25] John VerWey, "Chinese semiconductor industrial policy: past and present," Journal of International Commerce and Economics, July 2019, https://www.usitc.gov/staff_publications/jice/chinese_semiconductor_industrial_policy_past_and.

[26] Amanda Lee, "China to curb 'chaos' in semiconductor industry and hold bosses accountable for risky, loss-making projects," South China Morning Post, October 20, 2020, https://www.scmp.com/economy/china-economy/article/3106307/china-curb-chaos-semiconductor-industry-and-hold-bosses.

lithography and advanced packaging.[27] Chinese AI companies have tried to gain access to high-end GPUs through smuggling, cloud computing services, and even repurposing gaming chips.[28] DeepSeek's latest breakthroughs with its V3 and R1 large language models show how Chinese AI firms are using algorithmic innovations to squeeze more performance from limited compute resources.

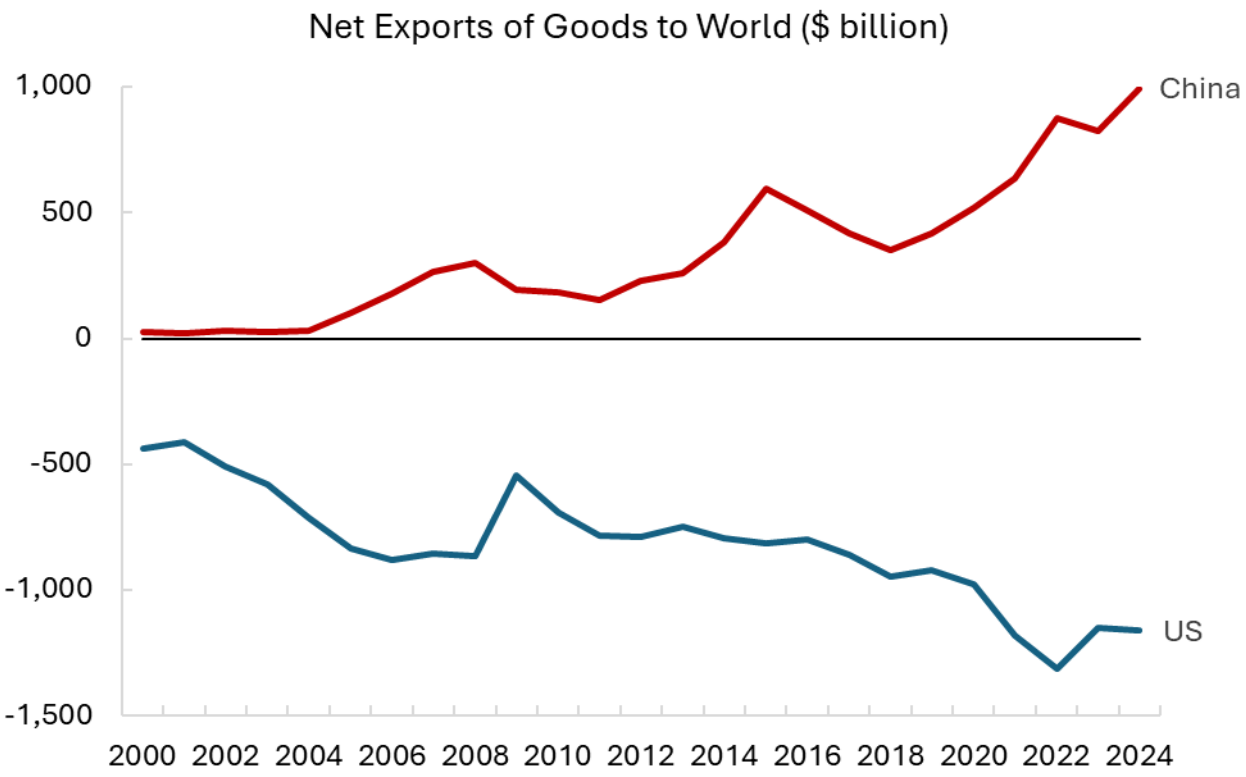
3. Going Global

Exporting goods to overseas markets is nothing new for China. Since the early days of China's reform era, China has tried to use exports to earn foreign currency and drive economic growth, following an export-led model of development pursued in a number of East Asian countries. In the late 1990s and early 2000s, China under then-President Jiang Zemin pursued a "going out" (走出去) strategy that encouraged Chinese firms to invest in foreign markets. More recently, President Xi Jinping's signature Belt and Road Initiative has sought to leverage Chinese financing and construction capabilities to develop infrastructure, particularly across the Global South.

International concerns or backlash over Chinese exports and outbound investment are also nothing new. China's exports of large volumes of inexpensive goods, such as steel and solar panels, have faced anti-dumping investigations from the U.S., Europe, and other countries since China's entry into the WTO, even stretching back to investigations into Chinese shop towel exports in the 1980s. Chinese efforts to acquire strategic overseas assets such as Midea's takeover of German industrial robotics firm Kuka or CNOOC's thwarted attempt to buy U.S. oil producer Unocal prompted security concerns from the U.S. and its partners. Indeed, when Made in China 2025 was published, Chinese firms appeared to target German firms in the ten key sectors of Made in China 2025.[29]

What is different this time is that China is now increasingly competing with U.S., European, Japanese, and Korean firms in high-value, high-tech industries they had once dominated. Previously, Chinese exports tended to be concentrated in lower-value, low-tech products that leverage China's advantages in lower labor costs as well as lower environmental standards and labor protections. These industries made up what became known as the first "China shock" in the U.S.: clothing, toys, footwear, furniture, low-end consumer devices, and other basic consumer goods. Over time, China began moving into higher-value goods, such as smartphones, home appliances, and industrial equipment. Already this shift in the structure of China's exports was becoming clear in the 1990s and early 2000s, corresponding to an increase in the complexity and

[27] Paul Triolo, "The evolution of China's semiconductor industry under U.S. export controls," American Affairs, November 2024, https://americanaffairsjournal.org/2024/11/the-evolution-of-chinas-semiconductor-industry-under-u-s-export-controls/.
[28] Ana Swanson and Claire Fu, "With smugglers and front companies, China is skirting American A.I. bans," The New York Times, August 4, 2024, https://www.nytimes.com/2024/08/04/technology/china-ai-microchips.html.
[29] Cora Jungbluth, "Is China systematically buying up key technologies?" Bertelsmann Stiftung, 2018, https://globaleurope.eu/globalization/is-china-systematically-buying-up-german-key-technologies/.



Data Source: UN Comtrade, China General Administration of Customs, U.S. Census Bureau
Note: US 2024 data is trailing twelve months to November 2024

sophistication of China's production capacity.[30] Now, driven in large part by industrial policy programs such as Made in China 2025, Chinese firms are gaining ground or even dominating advanced manufacturing and high-tech industries, such as electric vehicles, batteries, shipbuilding, semiconductors, and industrial robotics.

The impact of China's industrial upgrading on the U.S. and other advanced manufacturing economies can be analyzed as a two-phase process. The first phase is a change within China's domestic market where foreign firms are gradually replaced with domestic substitutes. This is currently happening in industrial robotics where Chinese industrial automation firms such as Inovance and Siasun have seized over half of China's domestic market from foreign incumbents such as Fanuc and ABB.[31] This is also happening in the auto sector where foreign automakers such as GM, Volkswagen, and Toyota that were once dominant China's domestic market are being squeezed out by Chinese rivals such as BYD and Geely.[32] In some cases, the process is

[30] Li Cui and Murtaza Syed, "The shifting structure of China's trade and production," IMF working paper, 2007, https://www.imf.org/en/Publications/WP/Issues/2016/12/31/The-Shifting-Structure-of-Chinas-Trade-and-Production-21297.
[31] Rachel Cheung, "Chinese robots hit the factory floor," The Wire China, December 15, 2024, https://www.thewirechina.com/2024/12/15/chinese-robots-hit-the-factory-floor-industrial/.
[32] Yoko Kubota and Clarence Leong, "Foreign carmakers fight to survive in China as market share dwindles," The Wall Street Journal, July 8, 2024, https://www.wsj.com/business/autos/foreign-carmakers-fight-to-survive-in-china-as-market-share-dwindles-09990a32.

incomplete or faces roadblocks. For example, Chinese automakers have been reluctant to reduce their dependence on foreign chipmakers, which supply over 90 percent of their semiconductor needs, despite the Ministry of Industry and Information Technology's (MIIT) push for them to adopt domestic alternatives.[33] But where this process has been successful, this "domestic substitution effect" has the dual benefit to China of not only supporting its domestic firms but also depriving foreign competitors of one of their largest and fastest-growing markets.

The second phase involves Chinese firms competing in foreign markets. In some cases, the success of Chinese firms in the domestic market translates well in foreign markets, such as in the consumer electronics sector. Intense competition within China's domestic market can produce firms that are highly competitive on the world stage with sufficient scale to take on global industry leaders. On the other hand, Chinese firms who have achieved success domestically face many challenges when entering foreign markets. First, Chinese firms competing in international markets must overcome the reputational costs associated with being a Chinese company, including perceptions of lower quality. Ironically, the negative quality associations with the "made in China" label today are a hangover from China's earlier export waves. Second, in foreign markets Chinese firms no longer enjoy the "home court advantage" of policies and political support that may have fueled their success over foreign competitors in China's domestic market. In fact, the opposite is likely to be the case where Chinese firms must contend with the "home court advantage" and outright protectionism in other countries, particularly in politically sensitive industries tied to large numbers of jobs such as the automotive sector. Third, Chinese firms face growing concerns over national security risks, particularly in high-tech sectors and infrastructure. Increasingly, security and economic concerns are blending together, amplifying the challenges that Chinese firms face in many countries.

International responses to China's new wave of exports have varied widely, and China in turn has adapted its strategy accordingly. The range of reactions to Chinese electric vehicle exports offers a useful example. At one end of the spectrum stands the U.S., which has imposed high tariffs on Chinese EV exports, differential subsidies that exclude Chinese EVs, and finally an outright ban on Chinese passenger vehicles and parts that are "connected" to the internet. Chinese automakers, which expected to be nearly shut out of the U.S. auto market, limited their efforts to establish a presence in the U.S. Chinese battery makers, such as BYD and CATL, have tended to pursue licensing partnerships with U.S. firms rather than building factories in the U.S. due to political opposition.[34] India is another country that has strongly limited the entry of Chinese EVs with some exceptions, such as the joint venture between India's JSW and China's SAIC.[35] At the other end of the spectrum are countries such as Thailand, Hungary, and Morocco, which have actively sought out Chinese EV and battery investment. These countries view Chinese investment as a means of developing their own auto industries into an export platform.

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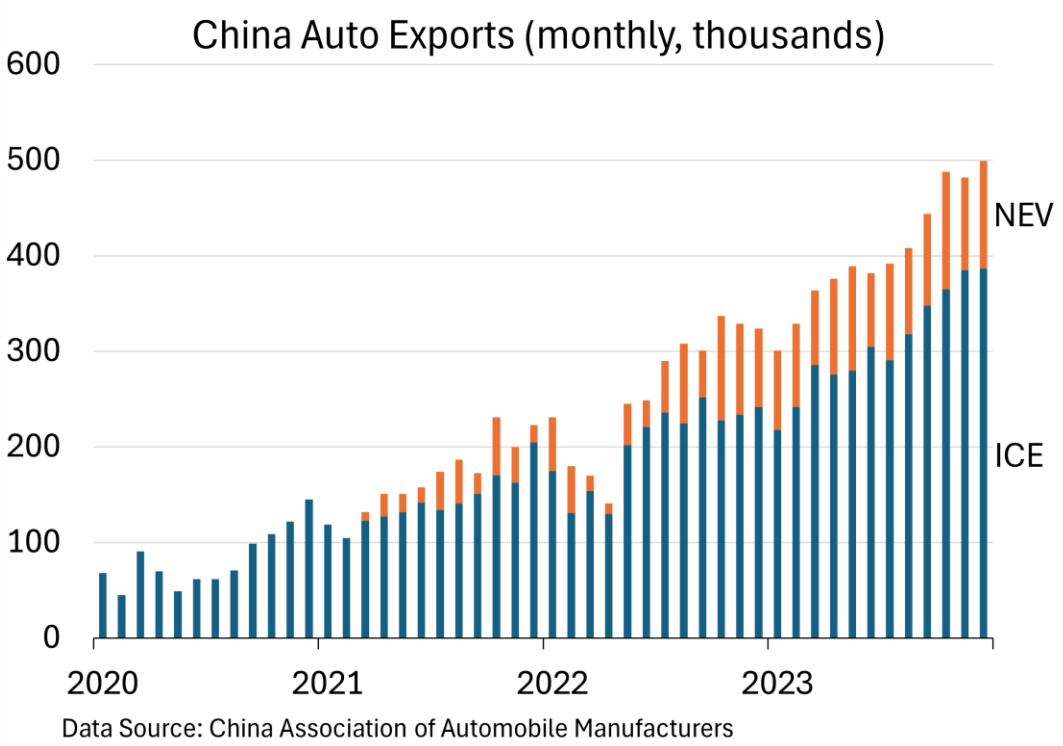
[33] Wency Chen, "China struggles to build car chip supply chain to break free of heavy reliance on imports," South China Morning Post, January 1, 2025, https://www.scmp.com/tech/tech-war/article/3292988/china-struggles-build-car-chip-supply-chain-break-free-heavy-reliance-imports.

[34] Zhang Yan and Kevin Krolicki, "Chinese battery giant CATL would build U.S. plant if Trump allows it," Reuters, November 13, 2024, https://www.reuters.com/business/autos-transportation/china-battery-giant-catl-would-build-us-plant-if-trump-allows-it-2024-11-13/.

[35] John Reed, "MG's Chinese owner and Indian steelmaker JSW team up to build electric vehicles," Financial Times, March 20, 2024, https://www.ft.com/content/160501a4-4ce9-4b86-bc75-c20dd3d2b57f.



Between these two extremes are countries and regions that have pursued a middle path that involves tariffs on Chinese EV imports as a tool to push Chinese automakers to set up factories domestically and localize production. The European Union, Brazil, and Turkey are examples of this middle path approach to addressing Chinese EVs. In each of these cases, Chinese EV makers, particularly BYD, responded with plans for new factories in these countries and regions. However, there are many important complications to this story. For the E.U., Beijing has imposed retaliatory tariffs and directed Chinese automakers to avoid investment in E.U. countries that voted in favor of tariffs.[36] The E.U. has also pushed Chinese automakers to share technology as a condition for E.U. subsidies.[37] However, China's Ministry of Commerce has told Chinese automakers to keep core EV technology in China.[38] Lastly, Chinese firms looking to expand abroad may run into compliance issues with local labor and environmental regulations, such as Brazil's recent investigation into "slavery-like conditions" for workers building BYD's new auto plant.[39]

[36] Zhang Yan and Kevin Krolicki, "China tells carmakers to pause investment in E.U. countries backing EV tariffs, sources say," Reuters, October 30, 2024, https://www.reuters.com/business/autos-transportation/china-tells-carmakers-pause-investment-eu-countries-backing-ev-tariffs-sources-2024-10-30/.
[37] Alice Hancock, Andy Bounds, and Alec Russell, "E.U. to demand technology transfers from Chinese companies," Financial Times, November 19, 2024, https://www.ft.com/content/f4fd3ccb-ebc4-4aae-9832-25497df559c8.
[38] Linda Lew, "China asks its carmakers to keep key EV technology at home," Bloomberg, September 11, 2024, https://www.bloomberg.com/news/articles/2024-09-12/china-asks-its-carmakers-to-keep-key-ev-technology-at-home.
[39] Fabio Teixeira and Luciana Novaes Magalhaes, "BYD brought hundreds of Chinese workers to Brazil on irregular visas, inspector says," Reuters, January 8, 2025, https://www.reuters.com/world/americas/byd-brought-hundreds-chinese-workers-brazil-irregular-visas-inspector-2025-01-08/.

Overall, Beijing has proven to be remarkably adaptable in its efforts to promote the global expansion of Chinese firms, tailoring its strategies to differing foreign market dynamics and changing course in the face of roadblocks. Across all of these country contexts, it is important to keep in mind that Beijing fuses together economic goals with broader geopolitical aims and its efforts to help Chinese firms "go global" are no exception.

Implications for the United States

Looking ahead, China plans to double-down on its push into advanced manufacturing and high-tech industries. Many of the target sectors in Made in China 2025 were named again in China's 14th Five-Year Plan[40] and the most recent Third Plenum economic roadmap, [41] including next-generation information technology, aviation and aerospace, new energy, new materials, and high-end industrial equipment. These industrial policy goals align directly with President Xi Jinping's focus on "high-quality development" (高质量发展) and "new quality productive forces" (新质生产力).[42]

China's determined efforts to lead the world in a range of critical, high-tech industries poses a distinct challenge for the United States. The conventional understanding of international market competition no longer applies. A growing number of industries are increasingly characterized as a binary outcome: the U.S. and its partners can either compete intensively or cede the market to dominance by Chinese firms. This problem is further exacerbated by structural issues created by China's industrial policy efforts. Within China, strong policy incentives for target industries frequently results in price wars and overinvestment by market players. To prevent what Beijing calls "vicious competition" (恶性竞争) or "excessive competition" (过度竞争), China tries to actively reign in firm behavior and maintain a balanced cohort of industry players through a process of "managed competition."[43] However, these cycles of Chinese overinvestment frequently cause pricing and volume fluctuations in global markets that make it difficult for private foreign firms to sustainably operate.

To address the challenges of China's industrial policy, the U.S. should pursue an array of strategies. For sectors where American firms are still dominant or competitive, such as semiconductor manufacturing and advanced industrial equipment, the U.S. should provide policy support to improve the international competitiveness of these firms and prevent them from going under in the face of difficult market conditions. It is much harder to restore industrial

[40] Xinhua News, "Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035 (中华人民共和国国民经济和社会发展第十四个五年规划和2035 年远景目标纲要)," March 12, 2021, https://www.gov.cn/xinwen/2021-03/13/content_5592681.htm.

[41] PRC State Council, "Resolution of CPC Central Committee on further deepening reform comprehensively to advance Chinese modernization (中共中央关于进一步全面深化改革 推进中国式现代化的决定)," July 21, 2024, https://www.gov.cn/zhengce/202407/content_6963770.htm.

[42] Xi Jinping, "Explanation of resolution of CPC Central Committee on further deepening reform comprehensively to advance Chinese modernization (关于《中共中央关于进一步全面深化改革、推进中国式现代化的决定》的说明)," July 21, 2024, https://www.gov.cn/yaowen/liebiao/202407/content_6963773.htm.

[43] Kyle Chan, "Inside China's state-owned enterprises: Managed competition through a multi-level structure," Chinese Journal of Sociology, 2022, https://journals.sagepub.com/doi/full/10.1177/2057150X221123388.

competitiveness after it is lost than to maintain it while it still exists. The U.S. should also limit the ability of American firms in high-tech industries to establish local manufacturing and R&D facilities in China. American firms should not be allowed to give away even outdated technology and know-how to China in exchange for short-term profits.

For sectors where American firms lag behind the global frontier, the U.S. should use industrial policy tools to protect its domestic manufacturing base and acquire cutting-edge technology and know-how from global industry leaders, including Chinese firms. This includes turning China's industrial playbook back on itself. The U.S. should leverage access to its own sizable domestic market to obtain investment and technology from industry-leading Chinese firms, particularly in batteries and electric vehicles. These partnerships should be carefully structured to maximize technology acquisition and job creation for the U.S.

Lastly, the U.S. should not be complacent with protectionist measures that shelter American firms within the U.S. domestic market but ignore international markets. The ultimate goal of U.S. industrial policy should be to develop and support American firms as global industry leaders that can outcompete Chinese firms around the world.

PANEL III QUESTION AND ANSWER

VICE CHAIR SCHRIVER: Thank you to all of our witnesses again. We will go in reverse alphabetical order, starting with Co-Chairs. And maybe I will just pick up your last point there, reversing the script, flipping the script and taking a page out of the Chinese playbook, to mix my metaphors here.

Aren't the Chinese too smart for that? If they invented the playbook and they saw how easily they were able to bring in U.S. talent, technology, JVs, et cetera, what would be the actual practical approach to flipping the script.

DR. CHAN: That is a great question. You are right, in a way. We exist in an era where this has already been done before, and China pioneered many of the strategies to do so.

What we can think about, though, is right now, as we speak, there are Chinese companies investing in plants in other parts of the world, in Europe, in parts of the global south, and even in the United States, to a certain extent. And there is a willingness, it seems, to engage in some kind of tradeoff or deal, possibly.

Now, that being said, there are already efforts, a lot of them informal, to limit the ability of Chinese firms to share, especially what they regard as core technology, like in electric vehicles. So that is clearly going to be an area of challenge. But there could be some avenue of opportunity in the midst of all that. Thank you.

VICE CHAIR SCHRIVER: So in other words, they are sort of onto the whole scheme a little bit. Thank you.

Dr. Naughton, you described the three phases, starting with targeted sectors, then innovation-driven manufacturing, and now the step change. To an uninitiated, uneducated, these seem like each new phase is a bit of a higher degree of difficulty to accomplish, and particularly moving to self-reliance, self-sustainability, it seems they are also part of a global supply chain network and reliant on other, not just our market but particularly for some input.

Can you handicap this step change and how successful they may be, and is this something that we need to actively work against them achieving, and perhaps that means remaining in their supply chains in some areas where we might be tempted to extract ourselves, just for the purpose of keeping leverage, et cetera?

DR. NAUGHTON: I think there are limits to our ability to guess how this is going to play out in different sectors, because it is very different in each case, and the Chinese, as Kyle said, they are very flexible. They know they are not going to be able to become completely self-reliant. So they are balancing costs and what they would consider to be dependency on a sort of case-by-case basis.

But absolutely. What this means is that both sides are engaged in a kind of partial managed decoupling. The Chinese, of course, deny it, but they are actually doing it much more than we are. And it is costly to them, and we need to manage it as best we can to minimize our costs and maximize theirs.

VICE CHAIR SCHRIVER: Thank you. Ms. Tobin, your ideas are, I would say, quite bold in some areas, reindustrializing the United States. I think since I was politically aware and conscious, every President has said we are going to bring manufacturing back to the United States, and it seems to be a long-standing objective.

But your point about the need to modernize manufacturing, I wrote down only 12 percent of plants use advance robotics. Isn't one of the challenges to that, one of the arguments to bring back manufacturing is actually employment and jobs, and the concern among many domestic

constituencies are that the advanced robotics actually work against that goal, even if bringing the manufacturing back helps with broader national interests and national security interests? And how do you deal with that?

MS. TOBIN: Talent is arguably the biggest chokepoint and obstacle to winning the tech competition with China. We are short 600,000 skilled manufacturing workers. So there are all these open jobs in the manufacturing sector, because over decades of de-industrialization, these people stopped going into manufacturing, learning these skills. That number is expected to grow to more than a million by 2030. So we simply don't have enough people to work in these factors.

So we actually need automation. We need robotics. China does too, because of their demographic downfall, so they are going gangbusters bringing in the robots because they need them to run these factories. We do too. So the issue is the U.S. has more cultural and political hurdles to automation than China does.

But for this audience, I think the key recommendations are, look, talent is absolutely key, and we need to be firing on all cylinders. We need to find a path for high-skill immigration reform. We also need to develop our own workforce and put a lot more resources into workforce training and development.

VICE CHAIR SCHRIVER: I appreciate it.

Commissioner Kuiken.

COMMISSIONER KUIKEN: Thank you, Commissioner Schriver. Ms. Tobin, one of the ideas that I have tried to sort of get into the bloodstream on Capitol Hill over the years is the idea of reinvigorating the National Defense Education Act, sort of a 2.0 version of it. This is one of the things that we used in the 1950s, post-Sputnik. Have you thought at all on this issue? Your workforce training comments or education comments seem to suggest that this is something that you are sort of arguing for. What is your reaction?

MS. TOBIN: So I am not an expert on the NDEA, but just again to return to the point of if this is about national focus on training up a workforce for manufacturing, then I am all in support of that.

I think that over the decades we have trended away from thinking about this career as something that young people want to go into. And, in fact, manufacturing jobs of the future, in these future factories that we are imagining, look very different than they looked in previous decades. These are software jobs. These are, again, industrial AI. These are very highly paid, high-tech -- these are tech jobs. We shouldn't be thinking about them as dirty, dull, dangerous manufacturing jobs. We should think of them as technology jobs.

So we have some factories of the future already going. Some of our larger firms -- Toyota, John Deere, and others -- are already running this way. The problem is that most of our manufacturers are small and medium-sized, 500 people or fewer, and so they just simply don't necessarily have the wherewithal, the expertise, the financial resources to upgrade to move into this phase of industrial AI, and that is where targeted government incentives can help fill that gap and connect them to these resources that our very largest and most advanced firms are already using.

COMMISSIONER KUIKEN: Thank you. Mr. Chan, one of the things we heard about this morning was the aerospace industry, and it is an area where the United States and Europe continue to sort of maintain a competitive advantage, at least in terms of the supply chain. You didn't touch on aerospace, but I would welcome your views on the aerospace industry, why Europe and the United States are still sort of experiencing success there, and how we should evaluate that in the context of some of your other recommendations.

DR. CHAN: Yeah. So I think some of the other panelists earlier spoke to some of the core technology issues that are involved. And it is interesting. There are parallels there between aerospace engineering and semiconductor manufacturing in terms of, again, access to some core technologies, also access to key manufacturing equipment, these two areas, that create bottlenecks and make it very difficult for new players to come in and challenge the few incumbents that are in this space.

But one thing that I would point out is that the effort to try to develop an aerospace, an aviation industry in China has been happening now for a number of decades, and I think will likely continue, keep on going, even if they run into issues, even if they feel like at this moment there is some success but not the kind of dramatic success that they hoped for, as with other industries.

So I will continue to watch this space because I think we shouldn't be comfortable with the idea that the technology bottlenecks are going to be enough as they stand today. There could even be more discussions about where we could create more restrictions or create more bottlenecks along the way, rather than hoping that naturally, is just a very hard engineering challenge to solve.

COMMISSIONER KUIKEN: Thank you. It looks like I have one minute left. Mr. Naughton, one of my Commissioner colleagues did this this morning, and I thought it was actually kind of a clever idea, which is, is there anything that is in your recommendations that you weren't able to get to in your opening statement? I recently heard you at a Chatham House Rules event. I won't tell you which event it was or anything else about it, but you said some very insightful things. So I want to give you a chance to take the floor for my remaining time on things you didn't get to say in your opening statement.

DR. NAUGHTON: I wish I knew what you were referring to. You know, I think that we are in a situation right now where China and the United States are locked in close embrace but also vitally essential competition. I think it is really incumbent on us to carry out a very strategic and limited decoupling, where we are trying to protect areas where we have clear technological advantage, but precisely because China is such a huge part of global manufacturing, we would be shooting ourselves in the foot to simply stop taking the large range of industrial commodities from China that are cost effective, in some cases subsidized by the Chinese government but that contribute to our cost competitiveness.

So I think it is really this kind of close-in competition is the world that we live in. Lots of American businesses still make lots of money in China, to a certain extent. Maybe their time there is limited. But we have enormous advantages, but it is just essential that we pick our battles very carefully. And if we pick our battles carefully and create some distance from the Chinese economy they are creating some tremendous difficulties for themselves, and I think we definitely are in a position to prevail against this very great threat.

COMMISSIONER KUIKEN: Thank you.

VICE CHAIR SCHRIVER: Commissioner Stivers.

COMMISSIONER STIVERS: Dr. Chan, in your testimony you described how specific U.S. and international companies have basically enabled the success of Made in China 2025. It is incredibly frustrating. We do have this fundamental challenge that you described, and very compellingly, about how these powerful companies are seeing a short-term advantage there but it is undermining our long-term national and economic security.

Many of us have seen clearly that this does undermine our security, but this also seems like yesterday's news. This has happened. It has made Made in China 2025 a success.

What sectors or companies should we be looking at, moving forward? Are there particular areas that Congress can shine the light on? Again, sectors or specific companies that you think we should focus on.

DR. CHAN: Thank you for your question. Some aspects actually of sort of high-tech manufacturing equipment. As I sort of mentioned before in relation to the aerospace industry, and especially in relation to the semiconductor industry, but elsewhere, the U.S. is actually still at the cutting edge in many respects for the actual manufacturing equipment itself. That is one area that I think you will get fewer household names, like Apple. But those are the sort of enabling, not quite foundational technologies, but they are sort of the enabling technologies that allow for this broader manufacturing capacity at the high end.

So I think it would be useful to do a more thorough review to figure out exactly which of these companies exist in the U.S., what their financial or economic conditions are, to what extent are they in a precarious state, could they use our help, or are they being coerced or challenged in some way by China. We should be thinking proactively about trying to find, identify, and then support those particular American manufacturers.

COMMISSIONER STIVERS: Thanks for that. Yeah, we do need a thorough review from somebody on what is coming next.

Are tariffs and restrictions on outbound investment, are those the best answers here?

DR. CHAN: Those are certainly tools that can be used, and to Professor Naughton's point, in a selective and strategic way they can be very effective. I think, for example, the use of tariffs, for industries where the U.S. is catching up, like batteries, those are areas where it would make sense, in fact, to borrow not just from the Chinese industrial playbook but from a well-known industrial playbook, to protect our sort of infant industries or protect our sort of startups and rising companies and efforts from being pushed out too early from the market.

And we have seen this happen again and again, where you have even companies that are supported within the U.S. But we ultimately let them fail, and then sometimes that technology then ends up going abroad. So I think we should think carefully about how we can use these to shelter and protect some of our strategic industries, especially as they are emerging. Thank you.

COMMISSIONER STIVERS: Thank you. Ms. Tobin, thank you for your testimony on the promote side. If nothing happens on the promote side, on your recommendations here, will we lose the technological competition with China?

MS. TOBIN: Yeah, I think the point I really want to get across is that manufacturing is this cross-cutting sector that is an enabler to all of these other critical and emerging technologies that we care about, from biotechnology to semiconductors to quantum to material science to robotics to all the rest.

We still have the opportunity to get this right, but I think this window is narrowing quickly. These two converging trends that I talked about, where an increasing number of firms that are producing in China are trying to diversify, they are looking at "China plus one" or "China plus two" strategies. They see the writing on the wall with the coming Trump tariffs, and they know that there are added incentives to reshore in the United States. But we need to incentivize them and help remove some of the hurdles.

So I think if we let things continue with the status quo, in a few years we will see the same thing happen in, say, robotics and automation and biotechnology that we saw in the 2010s and the early 2020s with 5G. We are starting to see it in 6G with China getting ahead in patents. I think we are starting to see the same writing on the wall in sectors where traditionally the U.S. has had a strong lead, like biotechnology and robotics. China is already ahead of us in certain

subsectors of robotics. We still have a lead in others. But there is currently no organized national public-private partnership or plan of action on manufacturing in robotics. There are a lot of people raising the alarm, but there is not sort of a concerted policy effort the way there has been in the last few years with chips.

COMMISSIONER STIVERS: Great. Thanks. Hopefully I will get another chance to ask about the rebuttable presumption recommendation. Thanks.

VICE CHAIR SCHRIVER: Commissioner Sims.

COMMISSIONER SIMS: Thanks, Mr. Chairman. Thank you all for your testimony today.

Ms. Tobin, I want to start with you because of some things you said in your opening statement, but if others have thoughts on this as we go I would love to hear from you, as well.

I like the way that you framed brute force economics. You said the variables in there are like force, scale, and ruthlessness. My background is in the intelligence community, so I think a lot about these issues through that lens. And one of the things that I have thought about as you were testifying was, number one, you made a comment, and I won't get this exactly right so feel free to correct me if this isn't exactly what you said, but effectively said the Chinese have outgrown this perception that they just steal stuff. They actually innovate now. So that is an interesting thing that has now come up in two of these panels today.

But what it makes me think of is China stole so much of our stuff for so long. They still steal our stuff all the time. And I am reminded that Stansfield Turner, who was CIA director in the Carter administration, made a comment in a congressional testimony once where he basically said, "if we spy for military security, why don't we just spy for economic security, as well?"

So when I think about Chinese advantages over us I think this word "ruthlessness" really sticks with me, because they are ruthless in ways that we aren't, and this is one of those areas.

So my question is, now that they are innovating, should we give stronger consideration to ramping up our own economic espionage and stealing from them. And if the answer is no to that, is that a moral judgment or is that an effectiveness judgment, that it just would not help us?

It is a long-winded question, but I would be curious your thoughts on that.

MS. TOBIN: Yeah, I think you are touching on a really big strategic issue that, as a nation, we are going to have to grapple with a lot in the coming years, of as China catches up to the United States, and even surpasses us in a growing number of technology domains, how does that affect our strategy?

The Chinese think of all of these things comprehensively, and they think in terms of comprehensive national power, and technology is one of the metrics, and economics is another, and military is another. And as they assess that their own comprehensive national power is increasing, that feeds back into their strategy-making process. There is a delay. But I think as they catch up and surpass us in more and more domains, we are going to maybe see some changes of strategic assumptions.

I think we do need to have our intelligence agencies have eye and ears on the ground in China. It is a very hard target. It is a very challenging environment. But I think given how the Chinese have blurred the lines between military and civil, between dual-use technologies, we need to be up to speed on what they are doing.

COMMISSIONER SIMS: But not just being up to speed. Should we steal their stuff? I mean, that is what they have been doing to us. Should we steal it and use it for the economic benefit of the United States?

MS. TOBIN: I think having this national conversation is very important. I don't think I

have the one-stop answer. But I am concerned that our ability to be on the ground in China, as intelligence agencies, has been so compromised in the past decade. The first question is can we even do that. What would a strategy look like to do that? I think a question that serious is going to be up to the President and up to the Congress to supervise.

COMMISSIONER SIMS: I don't blame you for not wanting to answer it. I am not sure I would want to answer it either. I don't know the answer. I mean, your comments about the ruthlessness made me think about turnabout is fair play, right? Like should we really give strong consideration to leveraging the U.S. intelligence community to help win this race in ways that we haven't in the past.

I don't know, Mr. Chan, if you have any thoughts on that.

DR. NAUGHTON: Can I jump in on this?

COMMISSIONER SIMS: You, as well. Anybody.

DR. CHAN: Yeah, just one quick thing. On the ruthlessness, actually I do think we should consider certain tools and strategies that have previously not really thought about as much before, and one of them, actually mentioned earlier by Commissioner Stivers, was more of the use of tariffs. I think we have been, in a sense, sort of ideologically fenced in by ourselves in thinking that we are supporters of a global free market system and we should sort of model that, to many extents.

And yet we see the sort of extreme measures that are taken on, for example, protectionist barriers, that China carries out, on not just U.S. products and on U.S. firms but European and sort of across our allies and partners.

So I think we might want to reconsider. We might sort of almost want to reset what we are willing to think about, and what would be considered fair to us And tariffs is one of those examples where we should really -- I don't know if it is going to be direct one-to-one match-up, but it is something where it has been very extreme on one side for a long time, and I think we should consider whether we might need to balance that out more proactively.

DR. NAUGHTON: Can I jump in on this?

COMMISSIONER SIMS: Sure. Go ahead.

DR. NAUGHTON: I mean, look, there is an immediate step we can take, which is to vastly ramp up the open source monitoring that is specifically directed at Chinese technological and industrial capabilities. We used to have some of those capabilities inside the U.S. government. They have pretty much dissipated. We need to rebuild them immediately, understanding that China has caught up in certain areas and has surpassed us in certain areas.

Monitoring, for instance, fusion research. China has at least three major fusion power research initiatives going on. As far as I know, the U.S. government doesn't track them. We should be.

COMMISSIONER SIMS: Thank you.

VICE CHAIR SCHRIVER: Thank you. Commissioner Price.

CHAIR PRICE: Thank you, and thank you all for participating today. We really appreciate it.

Dr. Naughton, I want to start with something that actually might relate back to your last comment. One of your notes in your testimony is that our primary tasks are to ensure that the U.S. prevails in competition. So I wanted to pick your brain a bit about how, like what specifically were you referencing in that last note?

DR. NAUGHTON: Well, I mean, clearly there are a range of very sensitive technologies -- I mean, AI, obviously, is at the top of everybody's mind right now -- where we made a kind of

national determination that this is absolutely fundamental to our security.

I think there are probably 20 specific subfields that we could identify as things that we should be investing more in and taking comprehensive steps to protect our dominance of certain aspects of these technologies. But that also means that there are hundreds of areas where our concern is really more with national competitiveness than it is with shared technological protectionism.

So I think we really need a kind of national effort, hopefully it would be bipartisan, that would develop smart reasoning in terms of how we do a partial decoupling.

For instance, my impression would be, look, if we encourage Chinese firms to invest in solar panels and batteries in the United States, that is good for us. You don't have to call it green energy. You can call it cheap, diversified energy, and we should all be able to get behind it. It doesn't have significant security implications, unlike, say, connected vehicles. And it also attracts Chinese capitalists who are chafing under the Xi Jinping regime that is imposing all kinds of restrictions on the Chinese economy, the Chinese market economy, and especially Chinese entrepreneurial capitalists. Let's bring those guys to the United States and help them contribute to U.S. concerns.

CHAIR PRICE: Thank you. And Ms. Tobin, you said in your testimony, as you were talking about pushing back, that you would get to some of those ideas in Q&A. So this is your moment to get to some of those ideas.

MS. TOBIN: Sure. Thank you. I think one thing that is on everybody's minds these days is DeepSeek and the questions that the Chinese launch of DeepSeek, very coincidentally on the day that we inaugurated a new President, is what does this say about U.S. export controls. And in my mind this only strengthens the case for doing everything we can to strengthen and protect and leverage the American advantage in hardware for AI, and that is, of course, the advanced AI chips and the data centers.

So DeepSeek made some impressive advances in some aspects of AI innovation. There are different ways to innovate in AI on the training side, and that is where our advantages in chips really matters. But DeepSeek's innovations were more on the inference side, so post-training when these models are doing the thinking. And they already had access to U.S. semiconductors. Some they got through smuggling, some they got before the controls were in place, and some they got legally. The Nvidia H20 chip is still available for sale, and DeepSeek was using that.

The point here is that we still need to strengthen and expand the export controls on chips. This is one of our key chokepoint advantages over China. And over time, as AI demands more and more computer, that advantage should strengthen, but only if we use it, only if we enforce those controls. I have put some ideas in my testimony for what we need to do to strengthen our system of export controls.

And the last thing I will mention before I let you follow up, if you like, with other questions, is that we can envision AI actually enabling BIS, making their job easier. So we are entering the era of AI agents, when we can have these AI assistants planning our vacations and doing all this great stuff. Why can't we work with our leading AI firms to develop agentic AI to support BIS, in monitoring, trade data, identifying idiosyncrasies, flagging things that a human agent needs to follow up on. BIS and our government agencies should be all over this, but they need support and the resources to do so.

CHAIR PRICE: Thank you.

VICE CHAIR SCHRIVER: Commissioner Miller.

COMMISSIONER MILLER: Thank you. I would like to take a minute to talk about the latest iteration of Made in China 2025, which is New Quality Productive Forces. As you are all well aware, this was a Xi Jinping mantra that became a program that was adopted by the NPC and then by the third plenum. And it essentially represents a whole-of-government effort to manufacture more, to produce more, to export more, particular of advanced technologies.

And this happens with the backdrop of the largest trade surplus in history, which is over $1 trillion in 2024, the largest goods surplus in history. And by 2030, if nothing is done here, the U.N. projects that global manufacturing value-add will be 45 percent Chinese, by 2030. These numbers are eye-popping. This seems extremely aggressive, and it seems potentially destabilizing to the global economy.

So my question is, why do think Beijing thinks they can get away with this? Is their expectation that the world is just going to smile and accept these trends indefinitely? Do you think that they believe there is no other reasonable choice? I would be curious to hear each of the panelists' response to this.

Perhaps, Ms. Tobin, you start.

MS. TOBIN: Thanks. It is a great question. They have gotten away with it before. We saw the China shock story before. Obviously, China was a smaller economy. You have made the point with great data that it is now 10x, 100x. Choose your X. But they got away with it for 20 years.

The CCP will respond to strength. They will keep pushing. They will keep pushing their over-capacity on the world as long as we let them. And so this is why it is encouraging to see nascent signs of countries taking action to protect themselves, put up tariff barriers, and others. But it is not enough.

I think that once a number of large economies, and here in the United States, and the EU and Japan and Korea and others are key, if all of us are starting to put up these barriers and saying no, that will get Xi Jinping's attention. But certainly I don't think he sees a serious enough resistance and pushback to make him think about changing this strategy.

Once his technology is integrated into the world, I mean, we have seen how hard it is to get rid of TikTok, we have seen how hard it is to get rid of Huawei around the world. So once it gets entangled it is hard to push out, and that is why we need to get ahead of the sectors where they haven't yet dominated.

COMMISSIONER MILLER: Dr. Chan?

DR. CHAN: Yeah. It is the big question that we are facing right now, and I think one thing that I would point out is that not only have they gotten away with it for a long time now, but I think there is a sense in Beijing that they have built up what has become a kind of mutually reinforcing industrial base.

What I mean by that is across not just one sector one industry, and not even just across the distinct industries or sectors targeted by, say, Made in China 2025, but across a huge range of overlapping manufacturing and high-tech areas, from, again, you can list the ones in Made in China 2025, you can actually list some of the new emerging ones. I think they have a sense that that creates sort of a self-reinforcing process that makes it very hard for other countries to sort of compete.

And we are seeing this already in a number of emerging technologies and emerging industries that build on China's existing strengths. One is, for example, drones, drone delivery, the rise of this so-called low-altitude economy, that builds off of existing strengths in China in drones, commercial drones in particular, sensors, sensor fusion technology, which overlaps with

AI more broadly, as well as a lot of the sort of micro-electronics, semiconductors, as well.

So you can see all that coalesce together in an almost sort of head start in a new industry, like drone delivery, and autonomous driving is another example, where you see this sort of combination.

So I think part of the danger here for us is that if we don't start to get our foot in the door for a number of these areas quickly, it will only allow China to sort of further cement its lead through this sort of self-reinforcing logic. Thank you.

COMMISSIONER MILLER: Thank you. Dr. Naughton?

DR. NAUGHTON: I think we can go a step further. I think the Chinese policymakers envision a bifurcated world, where China is the central manufacturing power with close relations with all of the Third World and lots of countries that are sort of in between the U.S. and EU. In other words, they envision having persistent, high-tech manufacturing surpluses that are compensated for by raw materials and labor-intensive goods that are coming from the Third World. And they don't think it through economically. They think it through strategically. I think Xi Jinping doesn't think economically. That is definitely not his forte.

But they are miscalculating, and one indicator of that is everybody is worried about Chinese EV exports. Guess what? Chinese EV exports in 2024 didn't increase, because countries aren't taking them. So I think we see exactly the kind of deep economic contradiction that Commissioner Miller is talking about here.

COMMISSIONER MILLER: Thank you.

VICE CHAIR SCHRIVER: Thank you. Commissioner Goodwin.

COMMISSIONER GOODWIN: Thank you, Mr. Chairman. Ms. Tobin, I want to talk about some of your pushback suggestions, and I suppose the rebuttable presumption idea resonates with the litigator in me.

You recommend that we create this presumption for certain critical technology sectors, drawing on what you call the innovation in the Uyghur Forced Labor Prevention Act. So I just wanted to flesh that out a little bit. What sectors, and who do you think should decide that? Whose burden is it? Would it be under the UFLPA as the importer? And then what should the burden be? Would it be the same sort of heightened standard, clear and convincing evidence?

And then what would the result be? Would it simply be access, or would it be, as you said in your written testimony, access to certain lower trade barriers? And then finally, who decides? Where would the decision-making authority for evaluating all this be housed?

MS. TOBIN: So yeah, the idea is inspired by the Uyghur Forced Labor Protection Act, this idea of a rebuttable presumption, where it is up to the importer to prove that there are not products made with forced labor out of Xinjiang before they get access to the U.S. market.

The idea is that we understand how the Chinese economy works, and we presume that the imports contain subsidies unless the importer is able to prove otherwise. I haven't mapped out all of the details of exactly how this work so I hope you will excuse that I am kind of riffing here.

But in terms of which sectors we would target, I mean, China has given us a lot of information there. They have many lists. There is Made in China 2025 list. There are a lot more updated industry plans, 14th Five-Year Plans. They have told us very clearly what sectors they are targeting for the Fourth Industrial Revolution. So I think we just take one of those lists and go with it, and that is going to cover most of the future industries that we care about.

What other questions did you have? Sorry, I didn't write them all down.

COMMISSIONER GOODWIN: So to rebut the presumption of subsidy, what would the standard be? What would the burden be? Would it be clear and convincing evidence, a

comparable standard as used in the UFLPA? And then what would the result be? If they are able to rebut that presumption, is it simply access to the market or would it be access to lower trade barriers?

MS. TOBIN: Yeah, I think they would have lower trade barriers. Now, this is going to be a very hard standard for them to meet, and I think my point in teeing this up is we need to have a strategy based on reality, and understanding that China is not a normal economy. You know, they abuse and exploit our system of rules and laws.

So it is going to be pretty unlikely that a lot of Chinese importers that are deeply embedded in China's military simple fusion system and the recipient of subsidies and all that are going to be able to meet this standard.

So the point is how do we recognize that we are not dealing with a normal trade partner, that generally meets trade commitments, that generally adheres to its WTO commitments? The WTO has all kinds of rules about reporting subsidies, and China doesn't keep to those.

So it is kind of drawing attention to this larger point that instead of continuing to torture ourselves by trying to treat China as though they are any other normal trading partner, we need to give them special treatment. And that also goes back to the idea of having a bifurcated system, a two-track system, the way we had under GATT before WTO.

COMMISSIONER GOODWIN: Let's talk about the promotion side of things. You may have heard the extensive discussion we had with our second panel about the role of investment in this strategic competition with China. And obviously you talk about reindustrializing the United States, expanding and investing in our manufacturing capacity.

But in your written testimony you do focus on increasing R&D funding towards certain breakthrough technologies. One of the witnesses on the second panel suggested Chinese are content to let that happen, as long as they control the inputs, the resources, and the markets. So I would just ask for your reaction to that suggestion.

MS. TOBIN: Yeah, I brought up R&D funding because the U.S. is incredibly negligent here. We don't really put much funding towards R&D in manufacturing. So Germany, Korea, Japan, and of course, China, really focus on this, and I think some of our competitors and allies put in 10 to 30 times the amount of funding into manufacturing R&D, compared to their GDP relative to us.

So we have not prioritized manufacturing innovation as a nation. We have a lot of R&D funding going into other areas, but this is simply a gap where we don't really prioritize it, because I think we decided to neglect manufacturing as a sector that we care about. So it is simply about reversing that.

I mean, despite how little attention we have paid to this sector over the past few decades, we have a lot of great innovation happening in manufacturing. I have been to these conferences with these robotics companies, and they are inventing all this great stuff. The problem is not a lack of innovation. It is diffusion and adoption of this technology at scale. So that classic problem of getting from the lab to the factory floor. And there, it is really about targeted government incentives, tax incentives, and others to help make it easier for our factories to adopt these inventions and these innovations that are still happening in the United States.

COMMISSIONER GOODWIN: Thank you.

VICE CHAIR SCHRIVER: Commissioner Friedberg.

COMMISSIONER FRIEDBERG: Thank you very much. Dr. Naughton, in your writings over the years you have described a very systematic process through which China's industrial policies have evolved, and you talked today about these three stages. Can you say more about, in

your view, what explains the timing of these shifts? Why 2006? Why 2016? Why 2020?

DR. NAUGHTON: Sure. I mean, I think the first turn, and one of the reasons maybe it sort of caught us napping a little bit, was that the first turn, in 2006, was really kind of natural in more of a light touch industrial policy, that came after China had exhausted this explosive growth period, when people were moving off the farm and into factories producing cheap goods. So that all made sense, and I don't think it was particularly alarming to us at the time.

But after 2016, on one hand you have Xi Jinping pushing a much more dangerous, strategic vision, and you also have their conviction, which I think we share, that there really is a technological revolution going on. So for all these reasons, China really decided that their long-term vision of greatness, of dominance, would be realized through this manufacturing superpower strategy. And I think Liza really captures the urgency with which it has been pursued in the last decade.

COMMISSIONER FRIEDBERG: Thank you. Would it be fair to say that each of these phases has been driven, whole or in part, by strategic considerations, geopolitical calculations, as compared to concerns about national welfare and economic growth? And you say this specifically about 2016, the IDDS. In 2020, it looks like that is also the case.

Are we looking at something which appears to be, or perhaps which we interpret as economic strategy, which is not, in fact, purely economic strategy?

DR. NAUGHTON: I think we have to conclude that. I mean, of course, we can't see inside Xi Jinping's mind. We don't know how he trades off these different factors. But certainly he seems to be driven by a strategic vision that he is willing to override economic considerations.

I mean, maybe compared to the other panelists, I would emphasize a little bit more that some of China's technological achievements really are market driven, but layered on top of that is this, just as you say, this strategic emphasis, which is what makes it so much more threatening to us, and we have to take it seriously.

COMMISSIONER FRIEDBERG: You described the goal of the current phase as, "It's an ambitious policy to reproduce in China as many elements of a modern production system as possible." Does that mean that, in your view, that they are aiming for something that approximates autarky?

DR. NAUGHTON: I think they understand that true autarky is both impossible and would be very costly. But they are a little bit schizophrenic. They want to achieve all the benefits of autarky without quite committing to the whole thing. And as Commissioner Miller pointed out, of course that is impossible. Of course there is a contradiction, but it doesn't seem to bother them.

COMMISSIONER FRIEDBERG: So you have described this process as one of partial managed decoupling. And it seems to me that China may be trying to decouple from us in certain respects. They don't want to be dependent on us for technology. I assume they would rather not have to depend on our market demand as much as they have. But in other ways it seems they are trying very hard to prevent us from decoupling from them. So it is a two-sided struggle.

DR. NAUGHTON: It is two-sided, for sure, and that is unavoidable. But at the same time, we should recognize that their policy is completely hypocritical. I mean, they denounce decoupling from others, then follow it themselves. And that is because they want to shape the forms in which it takes, where they can maintain as much access as possible in certain critical areas, when they can't substitute it, but then substitute for the ones where they can.

COMMISSIONER FRIEDBERG: Last question. Why the urgency now? What is it? You described the policymakers as being impatient with market-conforming mechanisms. Is that part

of Xi Jinping's sort of general inclination towards statism? Is it based, do you think, on a perceived increase in risk of conflict that makes it more important for them to achieve these goals sooner?

DR. NAUGHTON: I think those are all factors, for sure. I think the first round of the trade war, of our side of the trade war, I think it shocked them and it scared them, and they decided that they would systematically reduce vulnerabilities. And I think they were very surprised in the fall of 2023, when the Biden administration not only cranked up the technological sanctions but made them much more finely targeted. I don't think they expected that the U.S. government was capable of that. So when it happened, that led to an even further sense of urgency on their part.

COMMISSIONER FRIEDBERG: Thank you very much.

VICE CHAIR SCHRIVER: Commissioner Brands.

COMMISSIONER BRANDS: Thank you. Ms. Tobin, I would like to pick up on your point about the arsenal of autocracy outstripping the arsenal of democracy. And I think that is really important, and it is an issue that is starting to get the attention that it deserves over the past two or three years, in large part because of what has happened in Ukraine. So I would be interested in hearing you say a little bit more about the dimensions of that challenge. Are there specific areas of the defense industrial base that particularly concern you? What does a strategy for dealing with those vulnerabilities look like? And then finally, how do you think about the issue of time and timing in thinking about this issue, where presumably your strategy might look different if you thought you had a 15-year timeline to a potential conflict than if you think you have a 3- to a 5-year timeline?

MS. TOBIN: I don't think there is a sharp distinction between our manufacturing industrial base as a whole and the arsenal of democracy or our defense industrial base. I think the innovations that I am so excited about, this industrial AI, offers potential. Some of the cutting-edge applications are absolutely dual use or have military applications.

I met with companies that are designing these factories of the future that can quickly produce parts for drones, for aerospace, for automotive. All of these things are dual use. And again, the problem is not coming up with creative ways to do this, coming up with innovations. The problem is scaling, and then there is a whole other set of problems with government organization and procurement.

So what we need to do, I think, is tear down some of these barriers that prevent these innovative companies from helping out the defense industrial base. They are knocking at the door, but oftentimes they don't know who to call, they don't know what door to knock on. I am sure you are very familiar with the problems with the DoD procurement system.

So in terms of your question of timing, this technology is here; it is happening. If we meet again next year it will be even different and even better. The problem is on the government side. The U.S. government has a unique ability to convene, and if you call these folks they will happily come. They will happy talk to you. They will happily sign up to offer these cutting-edge technologies very quickly. But the problem is on the government side.

COMMISSIONER BRANDS: And could you maybe say a little bit about how you think about the multilateral or the coalition aspects of this? In theory you could say there are certain things that the U.S. has to have the sovereign capability to produce, and then maybe there are certain things that we can lean on allies for help in producing, if you are thinking about shipbuilding or something like that. The gap is just too severe for the U.S. to make it up on a unilateral, national basis.

So is there a way of conceptualizing things that we can do in cooperation with key allies and partners to create sort of a more resilient, democratic industrial base?

MS. TOBIN: Sure. Our allies and partners certainly have a role. The U.S. is, far and away, the leader, with China close behind us, in AI. But I think when it comes to things like shipbuilding and drones and other select technologies, certain aspects of the semiconductor stack, some of our allies are in the lead.

So there is strategic and economic and defense value in building a system that integrates them. Korea, on shipbuilding, of course. The Netherlands and Japan on the semiconductor stack. Japan and Korea, as well. In drones, I was encouraged that Taiwan is trying to kind of restart their industrial base there. Hopefully Ukraine can get to a point, there will be peace when they can sell drones to the world. So there is absolutely a role for allies and partners in a way that is economically desirable.

And the point here is that the U.S. has the world's biggest market. We have enough weight that we can throw around in many contexts. But in some situations, even the massive market demand of the United States, the massive market demand of the Pentagon, isn't enough to create the demand pull that industry needs to jumpstart production of some of these technologies that take a long time to develop and a long time to build, and the market mechanisms aren't there. So combining the market demand of democratic market economies is going to be the key there.

COMMISSIONER BRANDS: Thank you very much.

VICE CHAIR SCHRIVER: Thank you. We have probably time for a second round if it is limited. So that sounds like it will take up the remainder of the time.

Commissioner Kuiken, and then Commissioner Miller.

COMMISSIONER KUIKEN: Ms. Tobin, Hal actually was going the direction I was going to go with you on the military industrial complex.

So research and development in manufacturing, I totally get the idea. Implementation of that is something that when you have that conversation, in a red state or a blue state, it is immediately perceived as job losses. I think I know how you are going to answer this, but I would really like to just hear you give the response on how we should think about that, in that context, because it does make it very difficult to sort of move forward in that policy space because of those concerns.

So what is your reaction to that, and then I have a follow-up.

MS. TOBIN: The job losses have already occurred. They were lost years ago to China. So where we are now is not having the workers we need to fill these factories. So we need an all-of-the-above approach. It is clearly a very sensitive political issue. Automation, you know, the word kind of triggers an allergic reaction in some quarters.

I think we need a public-private marketing campaign to envision what these very technology-oriented manufacturing jobs look like, and get people excited. And this is everything from apprenticeships to industry-sponsored training programs. There are a lot of small-scale things happening, but the problem is they are quite dispersed. Some things happen at the local level, the state level, some Federal programs. No one has got the stick. We don't have a national advocate for manufacturing and manufacturing workforce, so we don't have someone kind of telling this positive story of what this can look like.

So I think instead of sort of framing all of this in terms of job losses, we have to develop this positive narrative between industry and government, and go out and pound the pavement with it.

COMMISSIONER KUIKEN: There is a ton of energy around the idea of revitalizing and improving the defense industrial base, which is something that Commissioner Brands was just talking about. I think what has been happening over the last few years is we are pouring money into shipyards and some of these facilitization issues. But my sense is that we are not pouring money into some of the very things that you talked about, which would actually deliver capability faster than the sort of efforts that we are pushing. I would like your reaction to that one.

And then the second one, and I am not sure if you are able to do this, but what have you seen as you have looked at this problem as to how China is approaching advanced manufacturing in shipyards, in their defense industrial base? Are you seeing them deploying advanced manufacturing capabilities? I assume you are. I would like your reaction there, as well.

MS. TOBIN: Yeah, in terms of shipyards, we are way behind there. I was out in Hawaii visiting one of my relatives, and one of my second cousins is a young college student who is going to school to learn about the shipbuilding industry in Pearl Harbor. And I asked him if artificial intelligence was part of his curriculum, and he was alike, "No, not yet." And I was like, holy cow. So we need to start there. I mean, this should be something that we are diving into head first.

China is absolutely all over this. A few years ago, again, to come back to robotics, they were behind in robotics. They were a net massive importer. They were importing robots mainly from Japan and Germany and other places. They still are dependent on robots, but they are starting to fill the gap, and import less and less, and start to deploy their own industrial robots.

They are vigilantly focused on the Fourth Industrial Revolution. The issue is they have been working at this for decades so they have a massive and very sophisticated industrial base. And when you are working on the factory floor you naturally find process innovation, ways to do things better. So they are all over that.

In terms of pouring money into the right thing, again, I keep kind of coming back to the small and medium-sized enterprises. But we need to give these guys a break, just make it tax incentives for taking on these digital systems, and getting the training, getting the infrastructure, the software packages, this adaptation to become digital, to enter the 21st century and to integrate AI and digital technologies in both existing factories and new factories. That is not a lot of money. We are not talking about another CHIPS Act -- that would be nice -- but you could do this for a whole lot less.

COMMISSIONER KUIKEN: Thank you.

VICE CHAIR SCHRIVER: We are just about at time, but Commissioner Miller, I think you can close us out.

COMMISSIONER MILLER: Sure. I would love to ask for an additional 45 minutes to dig deeper into Ms. Tobin's pushback strategies, which I note are very much the same strategies identified as critical in our Key Economic Strategies Hearing last year. But I won't do that, mindful of time.

I do want to ask a final question, though, that we asked of the other two panels of experts. A very simple, very brief response only.

How would you best characterize export controls on key technologies in the areas of your expertise? Would you call them absolutely critical? Useful? Not Important? Or counterproductive?

Each one of you, very briefly.

MS. TOBIN: Essential.

DR. CHAN: Absolutely critical.

DR. NAUGHTON: I agree, critical.

COMMISSIONER MILLER: Thank you all.

VICE CHAIR SCHRIVER: Well, with that I will close out the third panel. Thanks again to the witnesses. This was really an excellent discussion, and I appreciate your insights.

Now it is time for Commissioner Kuiken's 45-minute closing.

[Laughter.]

COMMISSIONER KUIKEN: Hopefully it will be less than 45 seconds in closing. Thank you again to all of our witnesses for their excellent testimonies today. You can find those testimonies as well as a recording of the hearing on our website, USCC.gov.

I would like to note that the Commission's next hearing will take place on Thursday, February 20th. The hearing title is "An Axis of Autocracy -- China's Relations with Russia, Iran, and North Korea."

And with that we adjourn.

[Whereupon, the above entitled matter went off the record at 3:30 p.m.]