SPECIAL COMPETITIVE STUDIES PROJECT

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Welcome to the Arena

Who's Ahead, Who's Behind, and Where We Are Headed Next in the U.S.-China Technology Competition

2025 Gaps Analysis Report

Contents

Introduction

The intensifying technological competition between the United States and the People's Republic of China (PRC) represents one of the most consequential dynamics shaping the 21st century. This rivalry encompasses critical sectors that define economic power, national security, and global influence. Both nations are advancing rapidly across emerging technologies, with strategies that reflect starkly contrasting priorities, governance structures, and resource allocations. This report, **Welcome to the Arena: Who's Ahead, Who's Behind, and What's Next in the U.S.-China Technology Competition,** aims to provide a comprehensive, data-driven examination of this evolving landscape, building upon the foundation established in the Special Competitive Studies Project's (SCSP) 2022 gaps analysis.[1]

This document is designed to fulfill five key purposes:

1. **One-Stop Diagnostic Resource for Policymakers:** Tailored for the incoming Presidential Administration, the report serves as a strategic guide, identifying opportunities, challenges, and insights to inform technology policy and decision-making.
2. **Analysis of How Nations Prioritize Critical Technologies:** The report examines how various stakeholders within the U.S. innovation ecosystem prioritize key technologies, revealing strategic alignment and divergence across sectors.
3. **Update from SCSP's 2022 Gaps Analysis:** This report incorporates new data and developments – across twelve strategically critical technology areas – reflecting significant changes in the technological and geopolitical landscape since 2022.
4. **Forecast Geopolitical and Technological Trajectories:** By analyzing trends, investments, and strategic initiatives, this document surveys potential geopolitical wildcards and forecasts possible future trajectories of these key technologies and their implications for the global competition.
5. **Simulate the Functions of a Theoretical U.S. Technology Competition Council:** By providing a structured and holistic analysis, the report demonstrates what a dedicated

[1] **Methodology Note:** In 2022, SCSP conducted a gap analysis ("Gaps 1.0") of twelve technology areas that we believed would drive the competition between the United States and China from 2025 to 2030. Now, three years after our initial analysis, we thought it would be an opportune time to revisit our previous assessment and do a comprehensive update. These twelve tech areas are derivatives of a broader set of strategic sectors we judge to be central to building national competitiveness (Mid-Decade Challenges to National Competitiveness): artificial intelligence, biotechnology, advanced compute and microelectronics, advanced networks, advanced manufacturing, and next-generation energy. We used a framework of analytic questions to select and examine these tech areas through three lenses: tech phenomena, competition factors with China, and the state of the U.S. innovation ecosystem (Harnessing the New Geometry of Innovation). We assert that the evidence selected for these conclusions should be a mix of quantitative and qualitative metrics of actual fielded capabilities that differ for each technology, using secondary variables like publication trajectories as indirect proxies for understanding real positional advantages.

U.S. Technology Competition Council's output might look like, emphasizing cross-sector collaboration and actionable assessments.[2]

This report seeks to equip policymakers, industry leaders, and researchers with the state of play needed to navigate the U.S.-China technology competition. By identifying areas of strength, vulnerability, and opportunity, it provides a roadmap to strengthen the United States' position in the global innovation ecosystem while ensuring long-term resilience and competitiveness. The following sections delve into each technology area, presenting a nuanced analysis of where the United States and China stand today, and where they may be heading in the years to come.

Key Findings

- **China's Dominance in Key Infrastructure:** China's sprawling manufacturing industrial base gives Beijing systemic advantages in capital-intensive sectors, such as advanced batteries and fifth-generation wireless networks (5G) infrastructure. Thanks to significant state investments, control over critical supply chains, and scalable manufacturing, China has daunting leads in these technology areas. Although the United States has made measurable progress in fielding some of these infrastructure-heavy technologies, supply chain gaps and bureaucratic red tape is hindering U.S. competitiveness.

- **U.S. Leadership in Emerging Technologies:** The United States maintains leadership in sectors such as artificial intelligence (AI), quantum computing, and synthetic biology, driven by strong private-sector ecosystems, global collaboration, and innovation in foundational technologies. However, China's centralized funding and focus on commercialization are narrowing the gap in these areas.

- **Divergence in Prioritization:** Over the past three years, some U.S. industry stakeholders have shifted focus to AI, fintech, and human-machine interfaces, while some U.S. government departments and agencies continue to focus on advanced networks and advanced computing.

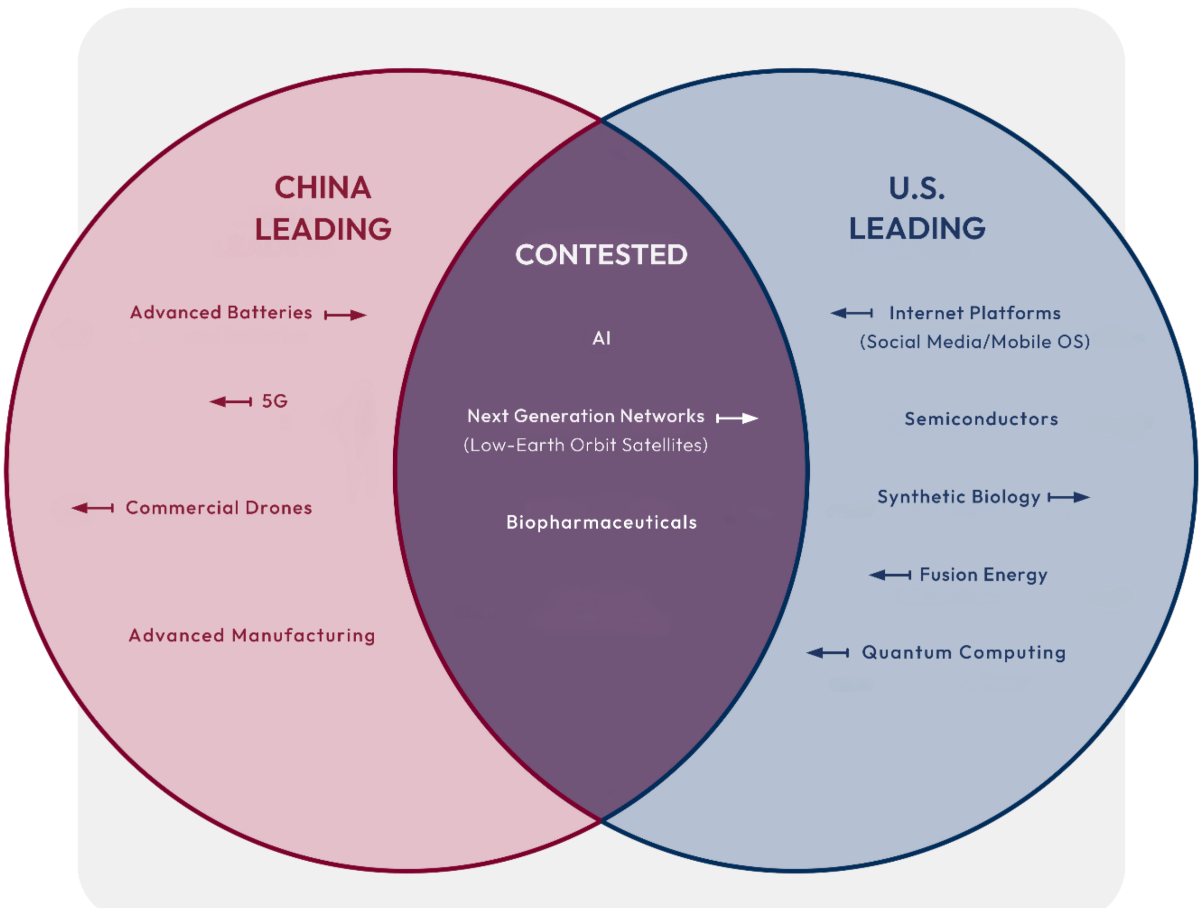
[2] The National Security Commission on Artificial Intelligence (NSCAI) in 2021 proposed the establishment of a Technology Competition Council (TCC), a recommendation that SCSP has echoed, to empower a single entity in the White House to set strategic direction and oversee a coordinated approach to technology competition. Furthermore, SCSP has proposed that the TCC and/or a new supporting entity such as an Office for Global Competition Analysis, conduct regular comparative analysis of U.S. and adversarial technological capabilities to better inform policymakers on how to prioritize resources and policy agendas. See Final Report, National Security Commission on Artificial Intelligence at 166 (2021); Harnessing the New Geometry of Innovation, Special Competitive Studies Project at 49 (2022).

- **Commercialization and Market Gaps:** While the United States leads in innovation, China excels in commercialization across sectors such as biopharmaceuticals and synthetic biology, leveraging its superior production infrastructure, biomanufacturing capacity, and integrated ecosystems.

- **Global Standards and Strategic Dependencies:** The competition extends to influence over global standards (e.g., 6G, quantum technologies) and strategic dependencies in supply chains. U.S. reliance on international production, especially in semiconductors and biopharmaceuticals, highlights vulnerabilities that China could exploit through economic leverage or export restrictions.

Leadership in Key Technologies Remains Contested

This graphic, last updated in 2024, summarizes SCSP staff's assessment of the current state of U.S.-China competition in specific technology areas, as well as the direction in which leadership in those technologies is trending through 2030.



Arrows Denote Trending Direction (Through 2030)

How Nations Prioritize Critical Technologies

In 2022, SCSP conducted a survey of 78 tech lists that outlined the current stated priorities of various government and non-government organizations in the United States, China, and around the world. From our analysis of the data, we published our "list of lists," an aggregated estimate of modern technology priorities.[3]

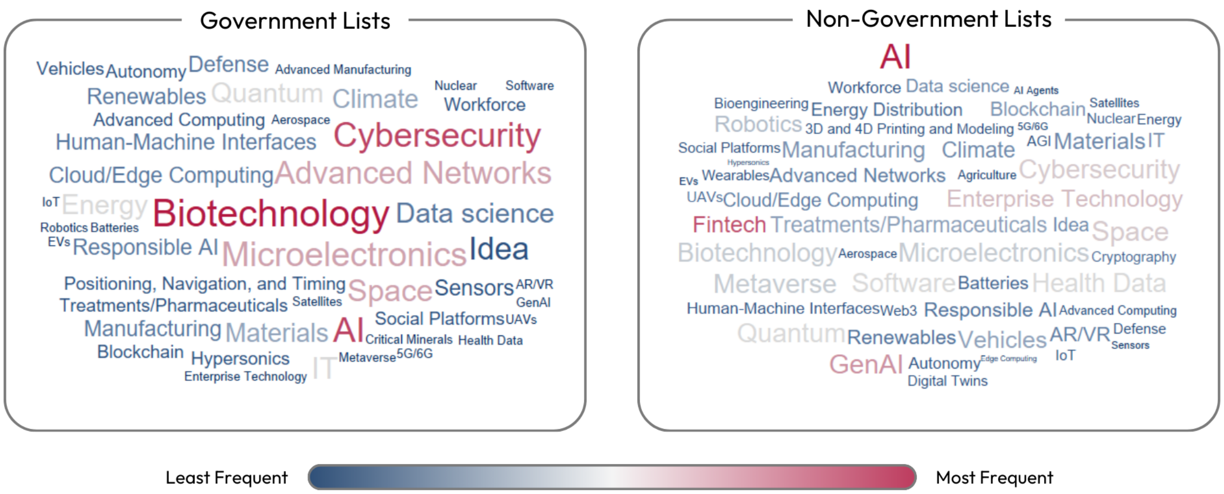
To construct this report, SCSP revisited this analysis to conduct an updated survey of the current state of priorities in the U.S. innovation ecosystem. Our researchers identified 112 new tech lists from the United States, China, and foreign allies and partners published or updated since 2022. In this section, we use this updated data to analyze how stated technology priorities have changed over time, compare across our allies and adversaries, and differ between government and non-governmental actors.

Which Technologies Have Risen and Fallen in Mentions Since 2022?

United States: Top Technology Priorities

Government Lists	14 Lists	Non-Government Lists	48 Lists
AI	12	AI	39
Biotechnology/Health	11	Advanced Computing	31
Energy	9	Biotechnology/Health	30
Cybersecurity	9	Human-Machine Interfaces	25
Advanced Computing	9	Cybersecurity	24
Space	7	Space	21
Advanced Networks	7	Advanced Manufacturing	20
IT	5	Energy	19
Human-Machine Interfaces	5	Mobility	19
Advanced Manufacturing	5	Autonomy/Robotics	17

[3] Our analysis breaks down each list by identifying the specific technologies mentioned and classifying them into different innovation categories. By counting how many lists each technology appears in, SCSP has crafted our "list of lists," highlighting the most widely prioritized technologies across different organizations and sectors. Our analysis aims to use these lists as a geopolitical proxy to gauge how nations and innovation ecosystem stakeholders think about technology priorities and spot differences between the stated priorities of organizations across the innovation ecosystem. We have chosen to focus narrowly on publicly released technology lists as a novel signpost of stakeholder priorities though many other indicators exist, such as investment trends and R&D spending. This analysis builds on SCSP's 2022 work, *What's in a Tech List?*, Special Competitive Studies Project (2022).



- **AI** and **advanced computing** industries have grown in priority dramatically across all U.S. technology lists. AI and advanced computing technologies have long been a top focus, but, since 2022, they've grown to represent 24% of all technology priorities listed. Mentions of **AI applications** – to include explicit mentions of AI, autonomy, or "smart" technologies – have also grown from 12% in 2022 to 22% in 2024, in line with broader industry growth in generative AI innovations.

- Among advanced computing innovations, **cloud/edge computing** and **quantum technologies** are prominently mentioned. Although quantum innovations remain the most frequently mentioned advanced computing technology priority among the U.S. lists SCSP tracked, since 2022, these technologies have fallen from representing nearly 34% of computing priorities in 2022 to 29% in 2024. Across the same time period, cloud and edge computing technologies have nearly doubled from 10% in 2022 to nearly 19% in 2024.

- As a proxy for the broader biotechnology sector, **health data** has become a new priority in this latest survey of U.S. technology lists. AI diagnostics, pandemic tracking, and other innovations have risen from representing 12% of listed biotechnology priorities in 2022 to 27% in 2024. Interest in data-informed health innovation has risen notably in non-government lists.

- **Advanced networks** and **autonomy/robotics**, despite consistently being in the top five listed technologies in 2022, have declined in mentions. Since 2022, advanced networks has been mentioned as a priority on 57% fewer occasions across U.S. government and non-government lists. Similarly, autonomy/robotics has seen the second-largest decline in mentions out of any technology, mentioned 40% fewer times.

- **Energy technologies** have remained stable as a priority. Since 2022, energy technologies have consistently represented around 7-8% of all technology priorities listed. Within energy technologies, nuclear energy innovation, including fusion energy, has grown from representing 10% of energy priorities in 2022 to 17% in 2024.

- **Cybersecurity**, on the other hand, has shot up in interest. In 2022, cybersecurity innovations were mentioned in only 11 out of the 40 total U.S. technology lists. Since 2022, these same technologies have become a top five priority in both government and non-government organizations. Particularly, in government lists since 2022, mentions of cybersecurity technologies have doubled.

United States: Changes in Tech Priorities

Since 2022, there has been an overall increase in U.S. priority of computing technologies (i.e. Software, IT, Compute, Enterprise Software, Cybersecurity, AI) and a decreased prioritization of hard infrastructure (i.e. Advanced manufacturing, Networks, Robotics).

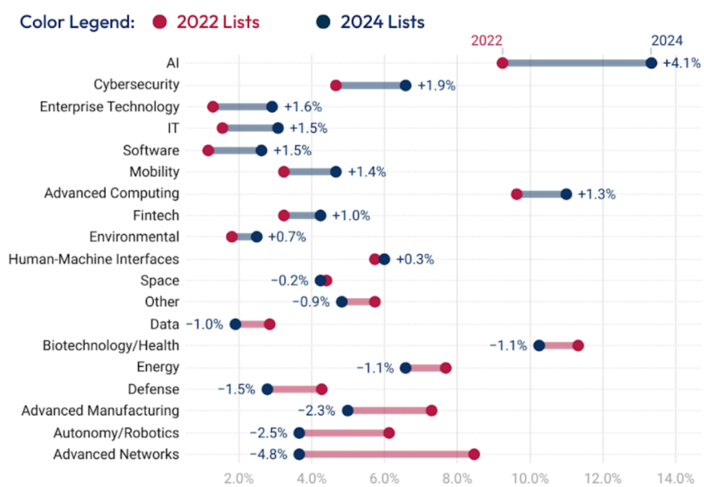


Chart: Author • Source: Special Competitive Studies Project • Created with Datawrapper

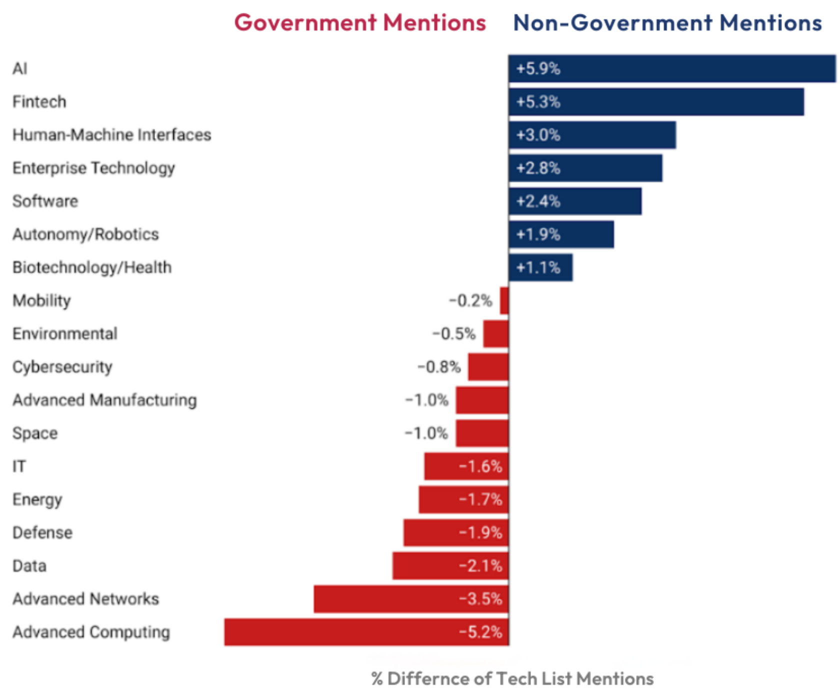
Technology	2022	2024
% of All Technologies		
AI Applications	12%	22%
% of AI		
Generative AI	4%	25%
Responsible AI	4%	14%
% of Biotechnology/Health		
Health Data	11%	25%
Treatments/Pharmaceuticals	25%	22%
% of Energy		
Batteries	17%	20%
Nuclear	10%	17%
Renewables	29%	24%
% of Mobility		
UAVs	12%	18%
EVs	12%	12%
% of Advanced Computing		
Cloud/Edge Computing	10%	19%
Quantum	34%	29%

Which Technologies are U.S. Stakeholders Focusing On?

Within the U.S. innovation ecosystem, industry and government organizations tend to have dramatically different technology priorities. From our split analysis of government and non-government technology lists, we identify that non-government organizations tend to prioritize computing technologies – such as AI, human-machine interfaces, software – at much larger proportions than government lists. Comparatively, government organizations have prioritized more traditional, hard infrastructure technologies, such as advanced manufacturing, advanced networks, and advanced computing.

United States: Difference in Government vs. Non-Government Priorities

In SCSP's 2024 tech lists dataset, we can identify clear differences between government and non-government priorities by comparing the % of technologies mentioned sources across various innovation sectors.



- **Non-government U.S. stakeholders Are the Drivers of Mentions of Fintech, Software, and Enterprise Technologies.** Out of the 14 government lists since 2022, these three technologies each represent less than 1% of the technologies mentioned. In fact, financial technologies are not mentioned once within government lists.

- **U.S. Private Capital Investors Are Focused on AI, Fintech, and Biotechnologies.** Out of the new 15 lists published by U.S. accelerators and investors since 2022, the top three technologies mentioned were in biotechnology/health, fintech, and AI. As one would expect, since ChatGPT's launch in late-2022, AI's prominence has grown, with 29% of industry listed technologies having explicit mention of AI, compared to 11% in 2022.

- **U.S. Government Lists Have Focused on AI, Advanced Computing, and Advanced Networks**, largely in line with Biden Administration priorities set out by policies including the 2022 CHIPS and Science Act, Executive Order 14110 on AI, and the National Artificial Intelligence R&D Strategic Plan.

Gaps Analysis

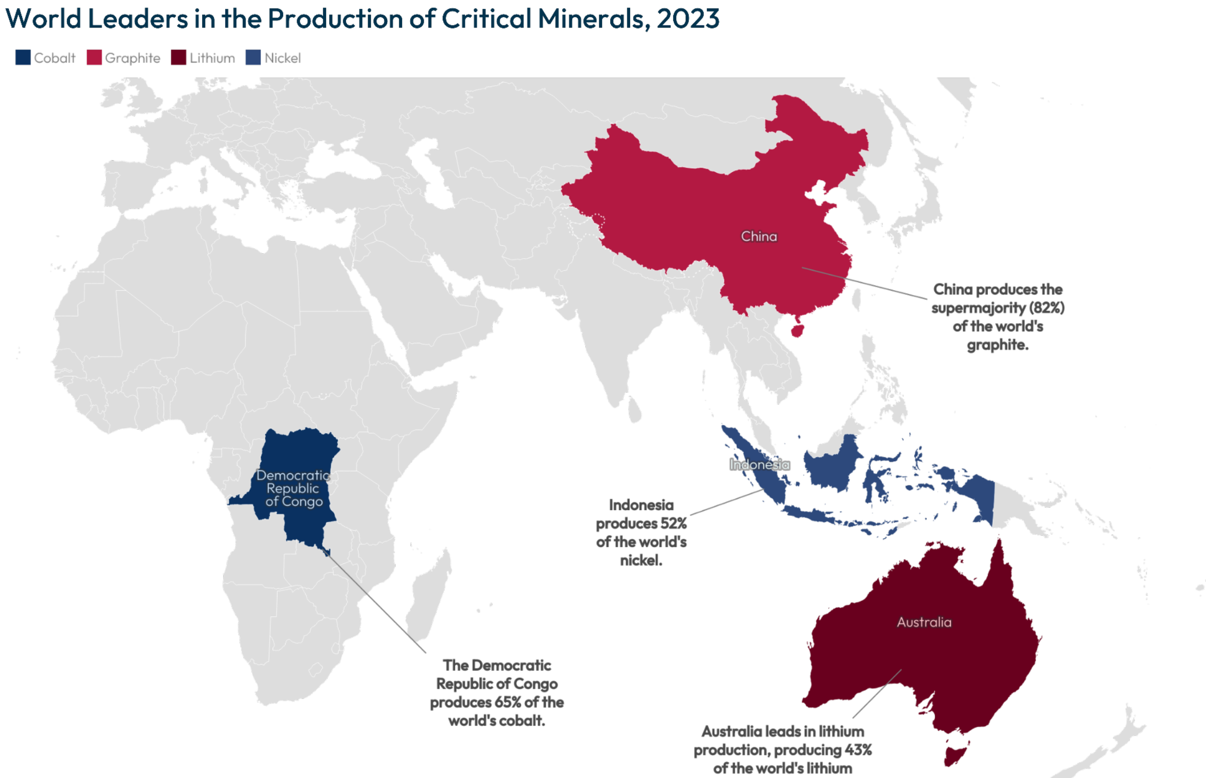
Advanced Batteries, 2025 Analysis

Assessment: **PRC-Lead**	Confidence Interval: **High**
Direction: **Trend Contested**	Confidence Interval: **Low**

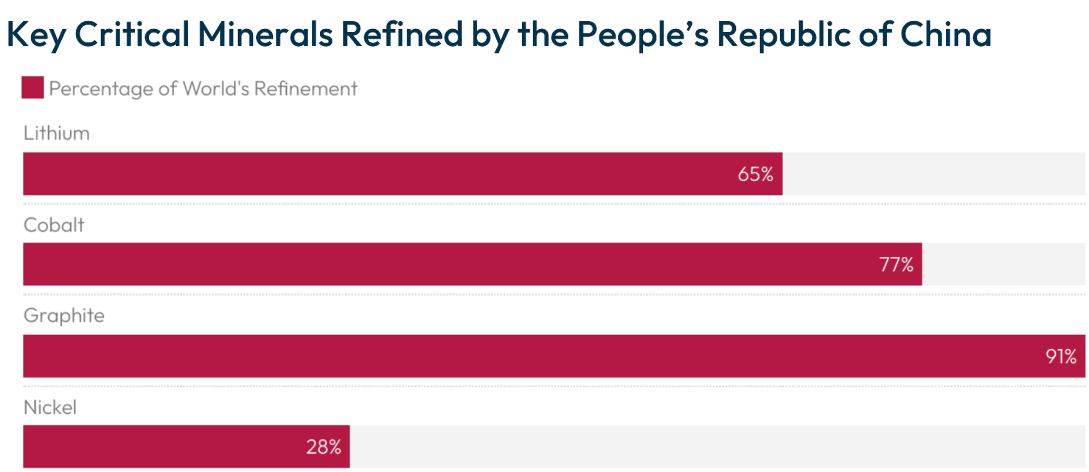
China Dominates Battery Production as the United States Aims to Close the Gap

Over the past three years, China's control over the advanced battery market has continued to strengthen, solidifying its position as a global leader in the field. The root of China's dominance in the advanced battery sector stems from its control over the critical minerals supply chain and its impressive battery production capacity, which both rely heavily on the nation's industrial manufacturing base and infrastructure-first industrial policies. Despite the geographical distribution of critical mineral production across several countries, China has strategically focused on refining minerals such as lithium and graphite, crucial raw materials in the battery manufacturing process.[4] China's dominance in these areas has allowed it to maintain a firm grip on the downstream battery supply chain, including electric vehicles (EVs) and a range of other battery-dependence platforms such as commercial drones, underscoring the strategic role critical materials play in the global supply chain.[5]

[4] Outlook for Key Minerals, International Energy Agency (2024).
[5] Jon Emont, China Harnesses a Technology That Vexed the West: Unlocking a Treasure Chest, Wall Street Journal (2024).



Source: Global Critical Minerals Outlook 2024, International Energy Agency (2024).



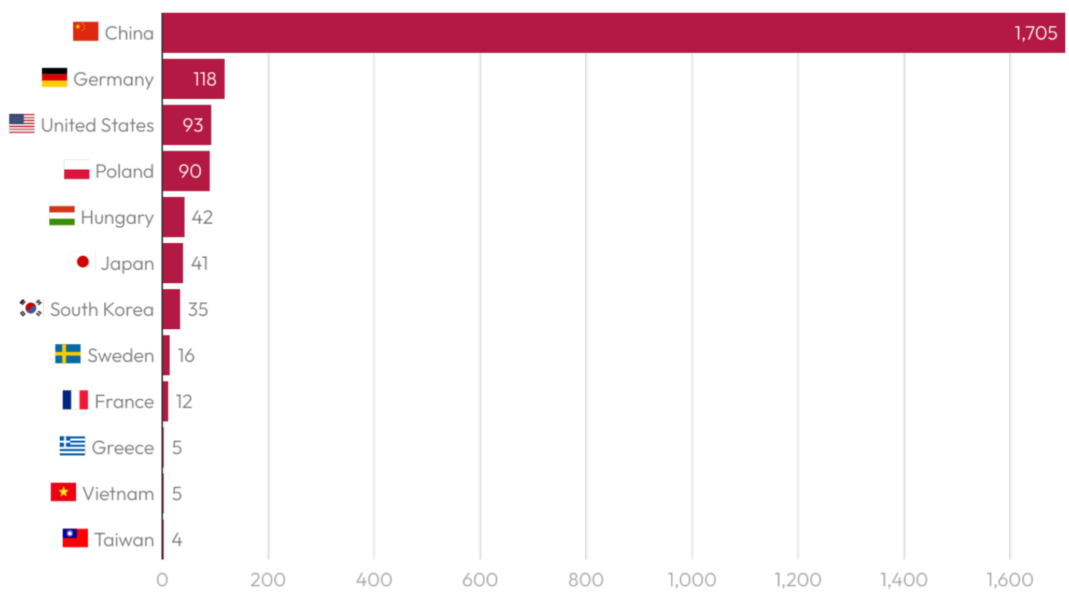
Source: Global Critical Minerals Outlook 2024, International Energy Agency (2024).

Beyond critical mineral mining and processing, China's battery manufacturing capacity also remains unmatched globally, producing a staggering 1,705 gigawatt-hours (GWh), dwarfing the

United States' 93 GWh in 2023.[6] This disparity is particularly evident in the lithium-ion segment of the sector, where China commanded 80% of the world's shipments of lithium-ion battery components in 2023,[7] accounting for approximately 60% of the global EV battery market.[8] PRC companies, led by giants like CATL and BYD, maintain their grip on the EV landscape, collectively accounting for over 50% of global market share.[9] Notably, no U.S.-based companies are among the top ten global EV battery makers.

Leading Countries by Battery Manufacturing Capacity Worldwide in 2023

(in gigawatt-hours)



Source: Leading Countries by Battery Manufacturing Capacity Worldwide in 2023, Statista (2024).

To bolster domestic advanced battery innovation and manufacturing, the United States has undertaken significant policy actions in the past two years, to include landmark pieces of bipartisan legislation like the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA). The BIL allocated over $3 billion to support 25 projects across 14 states for domestic battery production.[10] Furthermore, the IRA included measures designed to incentivize consumers to purchase EVs with batteries made in the United States and provided tax credits to manufacturers to build new battery facilities.[11] As a result of these initiatives, the number of battery facilities in

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[6] Leading Countries by Battery Manufacturing Capacity Worldwide in 2023, Statista (2023).
[7] China's Market Share in Key EV Battery Components Tops 80%, Nikkei Asia (2024).
[8] China Already Makes as Many Batteries as the Entire World Wants, Bloomberg (2024).
[9] Lei Kang, Global EV battery market share in 2023: CATL 36.8%, BYD 15.8%, CNEV Post (2024).
[10] Biden-Harris Administration Announces Over $3 Billion to Support America's Battery Manufacturing Sector, Create Over 12,000 Jobs, and Enhance National Security, U.S. Department of Energy (2024); Battery Materials Processing Grants, U.S. Department of Energy (2024).
[11] Owen Minott & Helen Nguyen, IRA EV Tax Credits: Requirements for Domestic Manufacturing, Bipartisan Policy Center (2023).

the United States has increased from two in 2019 to more than 34 in 2024.[12] Over the past two years, U.S. investments — both public and private — in batteries and critical minerals refining has grown at least threefold, with battery manufacturing investments totaling nearly $43 billion from 2023 to 2024.[13] Overseas, the United States is working to strengthen the battery supply chain alongside allies and partners through recent initiatives such as the Minerals Security Partnership (MSP) and the Indo-Pacific Economic Framework for Prosperity (IPEF).[14] These initiatives aim to bolster the battery supply chain by promoting responsible sourcing and investment in critical minerals among members. Continued prioritization of and investment into the United States' battery industry will be critical to reduce dependence on China.

Wildcards

- **Are Tariffs and Other Market Restrictions on PRC EVs Too Little Too Late?** Washington is implementing measures to prevent PRC-made EVs from flooding the U.S. market — including 100% tariffs and restrictions on PRC-origin interconnected vehicle hardware and software.[15] U.S. allies are taking similar actions. The EU imposed a lower, provisional anti-subsidy tariff of 45.3%, while Canada increased its 6.1% import tariff on Chinese EVs to 100%.[16] But these tariffs differ in aim: the United States views tariffs as one element of a larger strategic toolkit to reduce dependency and bolster domestic capabilities, whereas the EU is using them as a targeted, rules-based mechanism to correct identified market distortions.[17] In response, China has both retaliated and adapted, exporting more hybrid vehicles and shifting some assembly to Europe to mitigate tariff impacts. Whether these measures effectively reduce reliance on China's entrenched EV supply chain — and at what cost — remains uncertain.[18]

- **Will PRC Battery Overcapacity Distort Global Markets?** While China's dominant position in battery production is impressive, it's accompanied by the prospect of significant overcapacity as the world transitions from internal combustion engines (ICE) to electric vehicles. EVs are by and large driving the demand for today's advanced batteries. In 2023, China utilized less than 40% of its maximum cell output, and the

[12] Tracking the EV Battery Factory Construction Boom Across North America, TechCrunch (2024).
[13] Lily Bermel, et al., Clean Investment Monitor: Tallying the Two-Year Impact of the Inflation Reduction Act, Rhodium Group (2024).
[14] Joint Statement on the High-Level Minerals Security Partnership Forum Event in New York City, U.S. Department of State (2024); Indo-Pacific Economic Framework for Prosperity, U.S. Department of Commerce (last accessed 2024).
[15] USTR Finalizes Action on China Tariffs Following Statutory Four-Year Review, Office of the U.S. Trade Representative (2024); David Sanger, et al., Biden Administration Proposes Ban on Chinese Software in Vehicles, New York Times (2024).
[16] EU, China Close to Agreement over EV Import Tariffs, Leading MEP Says, Reuters (2024); João da Silva, Canada Hits China-made Electric Cars with 100% Tariff, BBC (2024).
[17] Francesca Ghiretti, Not All Tariffs Are the Same: The Core Differences between U.S. and EU Tariffs against Chinese EVs, Center for Strategic and International Studies (2024).
[18] Melissa Eddy & Jenny Gross, Europe Imposes Higher Tariffs on Electric Vehicles Made in China, New York Times (2024).

country's installed manufacturing capacity for cathode and anode active materials far exceeded global EV cell demand.[19] To alleviate this excess, China has become the world's largest exporter of EV cells, cathodes, and anodes, and CATL — China's largest battery manufacturer — is considering pulling back on lithium production, demonstrating some of the early signs of oversupply amid weak demand.[20]

What to Watch

- **AI Innovations Likely to Yield New Advanced Materials and Battery Chemistries.** AI innovations in battery-related R&D could transform the energy storage sector and will be the lynchpin for the United States and its allies and partners to regain an upper hand in the sector. AI has already accelerated the search for novel battery chemicals, narrowing 32.6 million possibilities to 18 promising candidates in under a week — a task that would otherwise have taken 20 years.[21] Deep learning AI models and programs like the Materials Genome Initiative are unlocking thousands of new materials for future technologies, like the next generation of long-duration energy storage.[22]

- **New Models of Public-Private Partnerships Could Supercharge Battery R&D.** New public-private partnerships in this space are also showing some promise: an AI-focused partnership between the U.S. government and industry early this year led to the discovery of a new kind of solid-state electrolyte that could cut down the amount of lithium used in a battery by as much as 70 percent.[23] However, the PRC has demonstrated an ability to rapidly move novel battery chemistries into mass production.[24] Additional progress in synthesizing AI-designed materials and scaling production for novel battery chemistries will be critical for the United States to catch up.

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[19] Outlook for Battery and Energy Demand, International Energy Agency (2024); Trends in Electric Vehicle Batteries, International Energy Agency (2024).
[20] Sherry Qin, Lithium Miners Shares Surge on Possible CATL Supply Cut, Wall Street Journal (2024).
[21] Accelerating the Discovery of Battery Materials with AI, Science (2024); Casey Crownhart, How AI Could Supercharge Battery Research, MIT Technology Review (2023).
[22] See for example, Jonathan Godwin, Introducing 'Orb' - The World's Fastest and Most Accurate AI Model for Simulating Advanced Materials, Orbital (2024); About the Materials Genome Initiative, Materials Genome Initiative (last accessed 2024); Amil Merchant & Ekin Dogus Cubuk, Millions of New Materials Discovered with Deep Learning, Google DeepMind (2023).
[23] Mark Johnson, New Battery Material that Uses Less Lithium Found in AI-Powered Search, Wall Street Journal (2024).
[24] Edward White, et al., Can Anyone Challenge China's EV Battery Dominance?, Financial Times (2023).

Advanced Manufacturing, 2025 Analysis

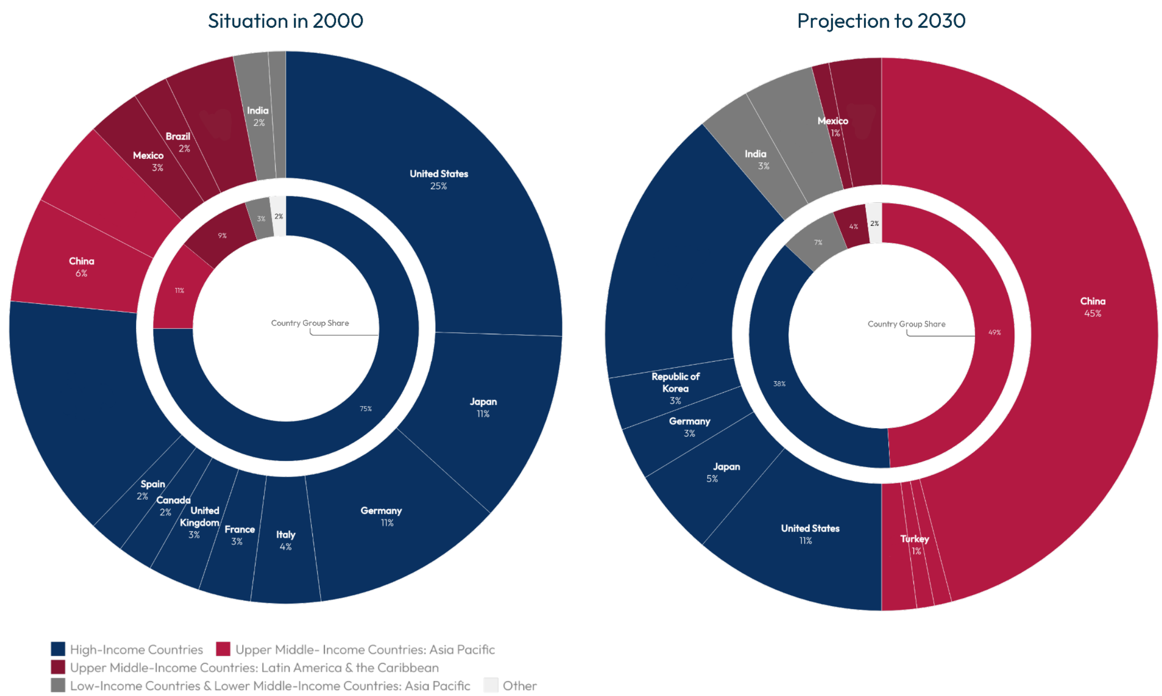
Assessment: **PRC-Lead**	Confidence Interval: **High**
Direction: **PRC**	Confidence Interval: **Medium**

China Supercharging Manufacturing Industrial Base, United States Looks for Leapfrogs

China leads the world in terms of manufacturing capacity and is responsible for nearly 35% of gross global output, followed by the United States at around 12%, with Japan, Germany, and South Korea following closely behind.[25] In recent years, the PRC government has identified advanced manufacturing as *the* primary basis of China's economic power, with PRC net lending to the sector rising from just $63 billion in 2019 to over $680 billion in the first three quarters of 2023.[26] Guided by a number of national strategies, China has established leadership positions across a range of advanced industries, from batteries to solar cells, electric vehicles, and legacy chips, and leads the world in terms of robotics deployment.[27] In 2023, PRC firms deployed as many industrial robots as the rest of the world combined.[28] These factors position China to capitalize on trends in automation and cement its position as the world's sole advanced manufacturing superpower into the decade.

[25] Richard Baldwin, China is the World's Sole Manufacturing Superpower: A Line Sketch of the Rise, Centre for Economic Policy Research (2024).
[26] Keith Bradsher, More Semiconductors, Less Housing: China's New Economic Plan, New York Times (2023).
[27] Alexander Brown et al., Robotics Sector + "Complete Industrial Chain" + Industrial Internet, Mercator Institute for China Studies (2023).
[28] Record of 4 Million Robots in Factories Worldwide, International Federation for Robotics (2024).

The Changing Structure of Global Industrial Production



Source: The Future of Industrialization, United Nations Industrial Development Organization at 17 (2024).

Despite China's status as an industrial powerhouse, various metrics suggest that, at the technology layer, advanced manufacturing remains a contested battleground. U.S. companies have a significant lead in generative AI, which is driving innovation across a range of advanced manufacturing activities.[29] More broadly, U.S. firms are pioneering novel manufacturing techniques and software-defined manufacturing paradigms which, if widely adopted across the U.S. industrial base, could offset PRC advantages.[30] Like the United States, China has experienced challenges in encouraging domestic manufacturing firms to adopt advanced manufacturing technologies: according to PRC state-affiliated sources, as of 2022, only 37% of manufacturers in China had reached a basic level of digitalization and industrial intelligence, while only 4% of PRC manufacturers had attained leading-edge capabilities.[31]

[29] Jacob Achenbach, et al., Harnessing Generative AI in Manufacturing and Supply Chains, McKinsey (2024).
[30] Action Plan for United States Leadership in Advanced Manufacturing, Special Competitive Studies Project at 15 (2024).
[31] China Electronics Technology Standardization Institute (中国电子技术标准化研究院), Intelligent Manufacturing Maturity Index Report (智能制造成熟度指数报告), (2023).

Wildcards

- **Will Humanoid Robot Adoption Take Off?** The widespread deployment of humanoid robots may materialize within the next decade, driven by advances in generative AI and significant venture capital investments. With manufacturing costs declining rapidly, robotic labor could become economically competitive with human labor. Yet critical barriers remain, including reliability and safety issues, perfection of training methods based on limited data, and cultural resistance to automation in the United States. China holds a significant manufacturing advantage, with domestic firms producing robots that are 80% as capable but 30% cheaper than U.S. models, backed by massive state investments.[32]

- **Will U.S. Cultural and Political Attitudes Stymie Robotics Deployment?** Recent strikes at U.S. ports demonstrate that some unions increasingly view automation with increasing suspicion.[33] Based on recent polling, citizens in the United States and other western countries tend to have more negative outlooks on the effects of automation than Asian countries.[34] The extent to which these differences in cultural attitudes shape the U.S. robotics deployment landscape has yet to be determined. However, they could significantly impact U.S. manufacturing competitiveness in the near future.

- **Will China Escalate the Use of Retaliatory Measures to Undermine U.S. Efforts at Reindustrialization?** Given its virtual monopoly on a range of advanced technology inputs, such as rare earth minerals mining and processing, China has significant geoeconomic leverage.[35] This leverage could be wielded to counter U.S. export control and investment screening measures. Indeed in December, Beijing imposed export restrictions on four critical minerals to the United States, a marked escalation in its retaliatory responses to U.S. policy actions.[36]

What to Watch

- **Will China Dominate the Robotics Hardware Stack?** China has long been a robotics importer, but PRC firms met over half of domestic demand for the first time last year.[37]

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[32] Robert D. Atkinson, How Innovative Is China in the Robotics Industry?, Information Technology & Innovation Foundation (2024).
[33] Heather Long, The Real Reason 47,000 Dockworkers Are On Strike, The Washington Post (2024).
[34] Courtney Johnson & Alec Tyson, People Globally Offer Mixed Views of the Impact of Artificial Intelligence, Job Automation On Society, Pew Research Center (2020).
[35] Gracelin Baskaran, What China's Ban on Rare Earths Processing Technology Exports Means, Center for Strategic and International Studies (2024).
[36] Keith Bradsher, China's Critical Minerals Embargo Is Even Tougher Than Expected, New York Times (2024).
[37] Will the United States or China Lead in Humanoid Robotics?, Special Competitive Studies Project (2024); Jacky Wong, China Needs More Factory Robots. Can It Build Its Own?, Wall Street Journal (2024).

Recent policy guidance[38] from Beijing seeks to establish China as the global manufacturing hub for humanoid robotics by 2027.[39] PRC firms already dominate downstream supply chain inputs, such as batteries, electric motors, and raw materials.[40]

- **Will U.S. Policy Continue to Emphasize Reindustrialization?** The Biden Administration worked with Congress to pass massive investments in advanced manufacturing industries, including EVs, energy storage, and semiconductors.[41] The incoming administration will likely continue to advance these efforts, while also using tools like tariffs to achieve industrial policy goals.[42] Efforts to rebuild U.S. manufacturing may come down to tax policy: extending expensing provisions for capital equipment from the 2017 Tax Cuts and Jobs Act would help drive robotics deployment.

- **Will China's Trading Partners Accept a China Shock 2.0?** PRC policymakers have identified advanced manufacturing industries, so-called "new quality productive forces," or sectors such as renewable energy technology and electric vehicles, as the basis of the PRC's economic growth into the near future.[43] As fears of China's industrial overcapacity mount, growing trade restrictions could reduce China's ability to export its way out of its economic slowdown.

Artificial Intelligence, 2025 Analysis

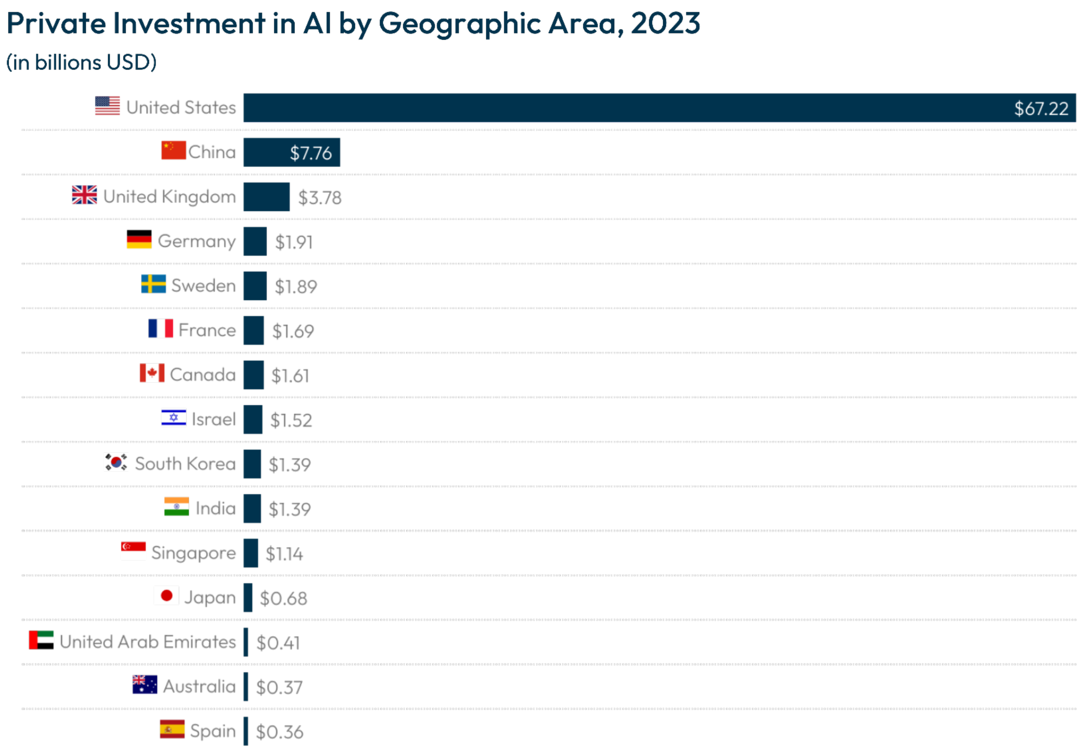
Assessment: **Contested**	Confidence Interval: **Moderate**
Direction: **Contested**	Confidence Interval: **Moderate**

U.S. and China Jockeying for Leadership in AI

The United States continues to have a robust AI ecosystem led by an established private sector, where a handful of large companies such as Anthropic, Google, OpenAI, Meta, and Microsoft

[38] Guiding Opinions on the Innovation and Development of Humanoid Robots" Was Issued: Reaching the World's Advanced Level by 2027, Ministry of Industry and Information Technology (2023).
[39] Will the United States or China Lead in Humanoid Robotics?, Special Competitive Studies Project (2024).
[40] Jacqueline Du, et al., Humanoid Robot: The AI Accelerant, Goldman Sachs (2024).
[41] Heather Boushey, The Biden-Harris Administration Has Catalyzed $1 Trillion in New U.S. Private Sector Clean Energy, Semiconductor, and Other Advanced Manufacturing Investment, The White House (2024).
[42] Dylan Butts, Trump Likely to Uphold CHIPS Act Despite His Campaign Rhetoric, Policy Experts Say, CNBS (2024).
[43] Arthur R. Kroeber, Unleashing "New Quality Productive Forces": China's Strategy for Technology-led Growth, Brookings Institution (2024).

have produced most of the world's foundation models in the last five years.[44] In 2023, private AI investment in the United States was almost nine times greater than the amount invested in China, the country with the second-highest investment, and 897 new U.S. AI companies were created.[45] The United States remains a top destination for top-tier AI talent,[46] but as big U.S. tech companies begin to turn more opaque in terms of research and development,[47] the number of AI patents[48] and publications produced by the United States are starting to slip.[49]



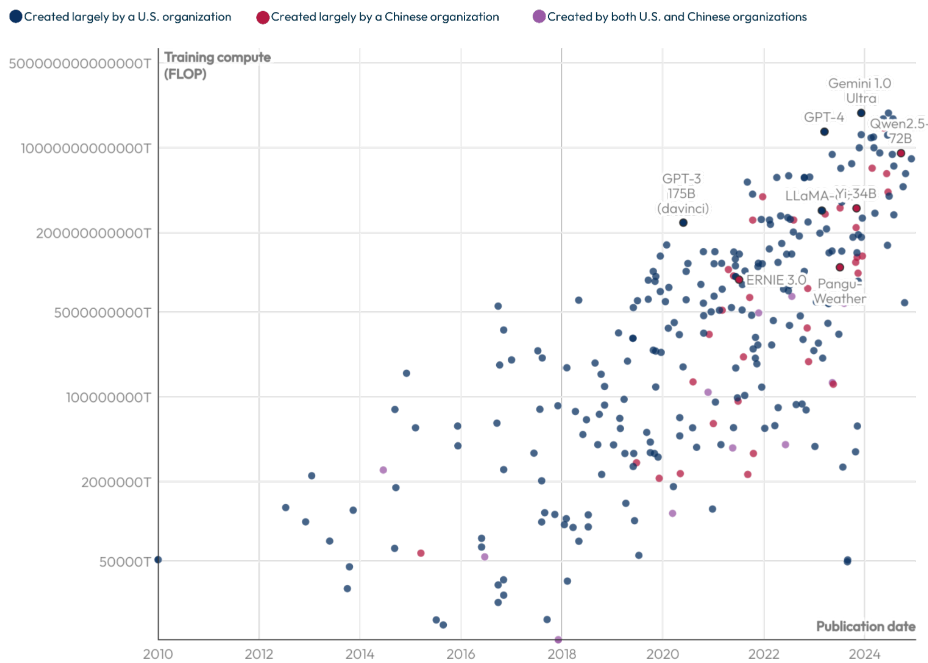
Source: Artificial Intelligence Index Report 2024, Stanford University (2024).

However, China has started to expand its AI ecosystem and has the most developers of large-language models worldwide.[50] The PRC's AI advancements are largely driven by academia and a handful of national champions like Alibaba and Baidu.[51] PRC universities and labs have become

[44] Artificial Intelligence Index Report 2024, Stanford University (2024).
[45] Artificial Intelligence Index Report 2024, Stanford University (2024).
[46] The Global AI Talent Tracker 2.0, MacroPolo (2023).
[47] Nathan Benaich, State Of AI Report 2024, Stateof.ai (2024).
[48] Country Activity Tracker (CAT): Artificial Intelligence, Emerging Technology Observatory (2024).
[49] Eliot Chen, Chinese AI Companies Are Catching Up Despite U.S. Restrictions, The Wire China (2024); China May Soon Be the Top AI Innovator in the World, New Report Finds, Information Technology & Innovation Foundation (2024).
[50] Paul Triolo & Kendra Schaefer, China's Generative AI Ecosystem in 2024: Rising Investment and Expectations, The National Bureau of Asian Research (2024).
[51] Eleanor Olcott, Chinese AI Groups Get Creative to Drive Down Cost of Models, Financial Times (2024).

leading AI research centers,[52] with Tsinghua University becoming a key hub for AI startups like Moonshot AI and Zhiphu AI.[53] Models produced by these startups and giants like Alibaba are competing against second-tier U.S. frontier models[54] with competitive edges like fluency in non-English languages[55] and various specializations, such as AI-generated text-to-video or vision capabilities. For example, PRC startup DeepSeek's V3 model is reported to outperform OpenAI's GPT-4o and Meta's recent version of Llama.[56] This increase in model capability is translating into real-world AI applications, like AI-enabled industrial robots.[57]

Notable AI Models, U.S. vs China



Note: Some leading-edge models lack publicly available data on FLOP and are therefore missing from the graph.

Source: Notable AI Models, Epoch AI (2024).

Wildcards

- **How Can China Utilize Open-Source AI to Overcome Restrictions on U.S.-Controlled Hardware?** Beijing is squeezing whatever efficiency gains it can acquire from open source

[52] ChinAI, MacroPolo (last accessed 2024).
[53] China May Soon Be the Top AI Innovator in the World, New Report Finds, Information Technology & Innovation Foundation (2024).
[54] Nathan Benaich, State Of AI Report 2024, Stateof.ai (2024).
[55] Sam Eifling, China's Biggest AI Model is Challenging American Dominance, Rest of World (2024).
[56] Kyle Wiggers, DeepSeek's New AI Model Appears to Be One of the Best 'Open' Challengers Yet, TechCrunch (2024).
[57] Artificial Intelligence Index Report 2024, Stanford University (2024).

as the U.S. and other countries tighten its access to AI hardware.[58] Open-source AI models can be accessed and used by anyone without restrictions, providing an alternative to U.S.-controlled technologies. In spite of the country's strict censorship requirements, China's leading AI firms have built high-performing open-source AI models that are on par with closed-source U.S. AI models.[59] Qwen, a family of AI LLMs developed by PRC Internet giant Alibaba, is among the most downloaded and most popular models on online repository Hugging Face.[60]

- **Will the United States Overcome the Energy Bottleneck in its AI Data Center Buildout?** AI growth, particularly the buildout of data centers and AI training facilities that require immense computational power, is placing unprecedented demands on U.S. electric infrastructure and could consume as much as 8% of U.S. electricity by 2030.[61] While major tech companies and utilities are racing to quickly expand electricity supply, these efforts may not be enough to address systemic problems within the U.S. power system that could constrain further AI development in the United States, like the permitting and regulation of next-generation energy sources.[62]

What to Watch

- **New Model Training Paradigms.** Distributed training runs, like those pioneered by startups such as the U.S.-based Prime Intellect,[63] create decentralized GPU networks that democratize computational power across multiple organizations, which could potentially solve the current resourcing and access challenges to model development.

- **A More General Form of AI Is on the Horizon.** The path to artificial general intelligence (AGI)[64] is accelerating through continuous improvements in large language models,[65] development of more complex AI capabilities such as reasoning,[66] and transformative advances across the AI stack, like quantum computing.[67] AGI could arrive as soon as 2025-

[58] Meaghan Tobin, China is Closing the A.I. Gap with the United States, New York Times (2024).
[59] Liza Lin, China Puts Power of State Behind AI—and Risks Strangling It, Wall Street Journal (2024); Wendy Chang, Large Language Model Development in China Thrives, But Geopolitics May Spell Trouble, MERICS (2024); Paul Triolo & Kendra Schaefer, China's Generative AI Ecosystem in 2024: Rising Investment and Expectations, The National Bureau of Asian Research (2024).
[60] Arjun Kharpal, China Wants to Dominate in AI — and Some of Its Models Are Already Beating Their U.S. Rivals, CNBC (2024).
[61] AI is Poised to Drive 160% Increase in Data Center Power Demand, Goldman Sachs (2024).
[62] Fortifying American Energy Dominance in the Age of AI, Special Competitive Studies Project (2024).
[63] Jack Clark, 10B Distributed Training Run; China VS the Chip Embargo; And Moral Hazards of AI Development, Import AI (2024); INTELLECT-1 Release: The First Globally Trained 10B Parameter Model, Prime Intellect (last accessed 2024).
[64] AGI Will Arrive In Three Ways, Special Competitive Studies Project (2024).
[65] Robots Learn, Chatbots Visualize: How 2024 Will Be AI's Leap Forward, New York Times (2024).
[66] Learning to Reason with LLMs, OpenAI (2024).
[67] Quantum AI: Harnessing the Power of Quantum Computing for AI, Special Competitive Studies Project (2024).

2027,[68] potentially disrupting entire economic sectors and representing a critical technological inflection point.

Biopharmaceuticals, 2025 Analysis

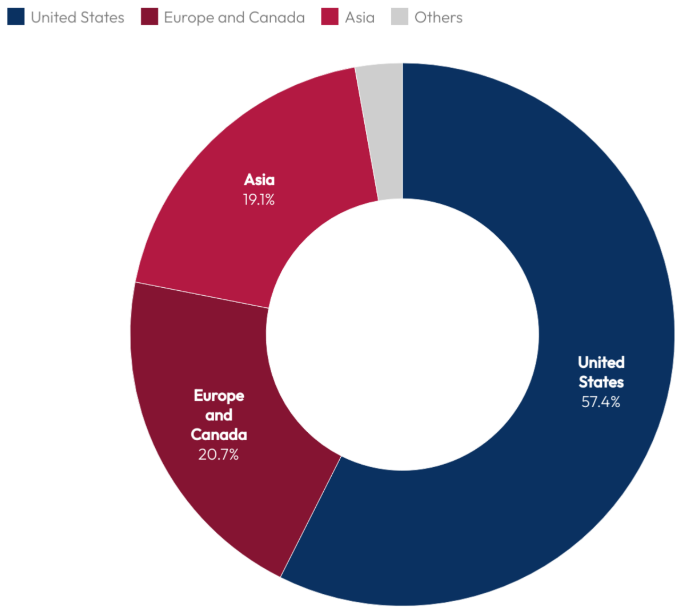
Assessment: **Contested**	Confidence Interval: **Moderate**
Direction: **Contested**	Confidence Interval: **Moderate**

The U.S. Lead in Biopharmaceuticals Continues to Face Rising Competition from China

The United States continues to lead in the initial stages of the biopharmaceutical value chain, supported by a regulatory environment that avoids government price controls, ensures strong intellectual property protections, and benefits from substantial public investment in research. National Institutes of Health (NIH) funding remains robust, averaging around $48 billion annually,[69] with roughly 83% supporting extramural research via nearly 50,000 competitive grants awarded to more than 300,000 researchers nationwide.[70] As a result, U.S. biotechnology firms command significant early-stage capital, attracting about $57 billion in 2023[71] — representing 35% of global biotechnology investment.

[68] In Good Company: Dario Amodei - CEO of Anthropic, Norges Bank Investment Management (2024).
[69] National Institutes of Health (NIH) Funding: FY1996-FY2025, Congressional Research Service (2024).
[70] Budget, National Institutes of Health (last accessed 2024).
[71] Brian Buntz, The Global Biotech Funding Landscape in 2023: U.S. Leads While Europe and China Make Strides, Drug Discovery & Development (2024).

Geographical Distribution of Biopharma R&D Venture Capital Investments, 2014-2024



Source: Biopharmaceutical Pipeline Funded by Venture Capital Firms, 2014 to 2024, Health Affairs Scholar (2024).

Meanwhile, China's "14th Five-Year Plan for the Development of the Pharmaceuticals Industry"[72] marks a notable pivot from merely adopting foreign innovations to actively pioneering them.[73] The National Natural Science Foundation of China (NNSF), its largest public science funder, expanded basic research and frontier exploration funding to nearly $5.2 billion[74] across 51,600 grants in 2022.[75] In the private sector, PRC firms secured about $21 billion in biotechnology investments in 2023 (12.7% of the global total).[76] These efforts have rapidly borne fruit, evident in the surge of China's global biopharmaceutical innovation share from 4.1% to 13.9% by 2020[77] and its rising slice of global biotechnology patents, now reaching 10%.[78] The United States still maintains a leading position, holding 39% of global biotechnology patents in 2020.[79]

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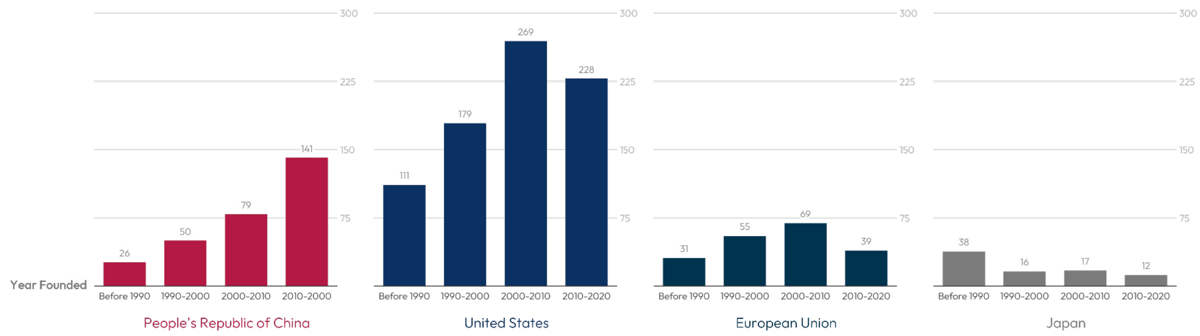
[72] Issuance of the 14th Five-Year Plan for National Drug Safety and High-Quality Development, National Medical Products Administration (2021).
[73] Sandra Barbosu, How Innovative Is China in Biotechnology?, Information Technology and Innovation Foundation (2024).
[74] China's Science Foundation Ups Research Budget to 33B Yuan, The State Council of the People's Republic of China (2022).
[75] 2022 Annual Report, National Natural Science Foundation of China (2022).
[76] Brian Buntz, The Global Biotech Funding Landscape in 2023: U.S. Leads While Europe and China Make Strides, Drug Discovery & Development (2024).
[77] Sujai Shivakumar, et al., Understanding the U.S. Biopharmaceutical Innovation Ecosystem, Center for Strategic and International Studies (2024).
[78] The Global Landscape of Biotech Innovation: State of Play, EU Science Hub (2024).
[79] The Global Landscape of Biotech Innovation: State of Play, EU Science Hub (2024).

The Number of New Chinese Biopharma Companies Has Risen Quickly



Source: John Wong, et al., Competing in China's Biopharma Market: Key Success Factors for Multinational Companies, BCG (2020).

A critical indicator of innovation leadership is the ability to bring novel drugs to market. Between the periods of 2000-2008 and 2009-2017, U.S. Food and Drug Administration (FDA) approvals rose by 44.5%.[80] By 2023, the FDA approved 55 new drugs,[81] including three from PRC developers.[82] In parallel, China's National Medical Products Administration (NMPA) approved 87 novel drugs in 2023, including five first-in-class drugs from domestic firms.[83] These outcomes highlight how China's regulatory reforms[84] have reduced approval backlogs and increased both imported and domestically developed medicines since 2011,[85] underscoring its growing ability to transform discoveries into marketable products.

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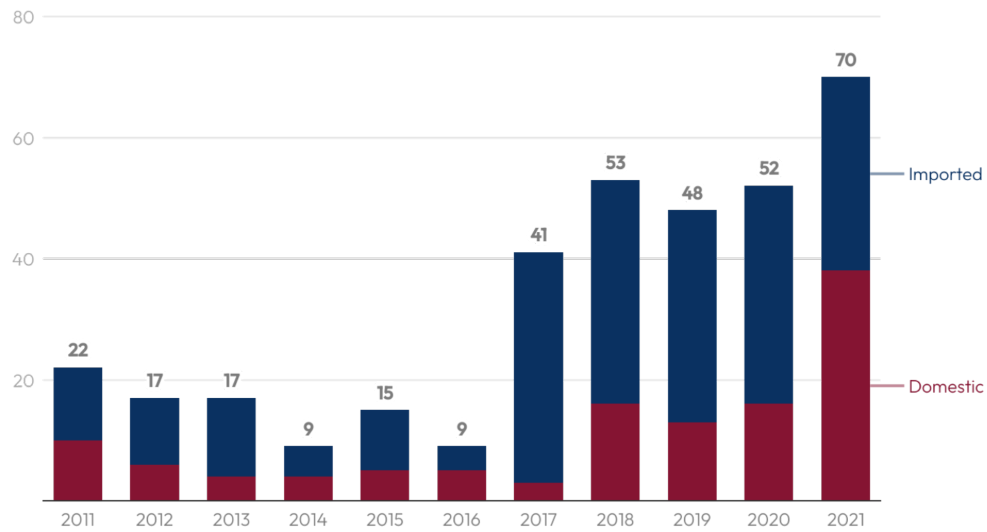
[80] Angelika Batta, et al., Trends in FDA Drug Approvals Over Last 2 Decades: An Observational Study, National Library of Medicine (2020).
[81] Novel Drug Approvals for 2023, U.S. Food & Drug Administration (2023).
[82] Lang Zheng, et al., Targeted Drug Approvals in 2023: Breakthroughs by the FDA and NMPA, Signal Transduction and Targeted Therapy (2024).
[83] Lang Zheng, et al., Targeted Drug Approvals in 2023: Breakthroughs by the FDA and NMPA, Signal Transduction and Targeted Therapy (2024).
[84] Lili Xu, et al., Reforming China's Drug Regulatory System, Nature (2018).
[85] Ling Su, et al., Trends and Characteristics of New Drug Approvals in China, 2011–2021, Springer Nature Link (2023).

Number of Domestic and Imported Drug Approvals by NMPA in China, 2011-2021



Source: How Innovative Is China in Biotechnology?, Information Technology & Innovation Foundation (2024).

Where the United States struggles to compete with China in biopharmaceuticals is, like in many other sectors, on the commercialization and production side of the value chain. Supply chain, regulatory, and production capacity factors have improved China's relative position. While the United States still led in 2020 with 28.4% of global pharmaceutical production (up from 26.2%in 1995), China's share climbed to 17.4% during the same period, a dramatic increase of 14.4%.[86] This shift is evident in trade patterns: in 2022, U.S. biopharmaceutical imports from China totaled $10.2 billion, outpacing exports of $9.3 billion.[87] Moreover, PRC firms now supply about 17% of U.S. Active Pharmaceutical Ingredients (APIs),[88] at a time when only 28% of API manufacturers are based in the United States.[89] Reflecting these dependencies, the U.S. biopharmaceutical trade deficit with China grew from $959 million in 2010 to $4.07 billion by 2022.[90]

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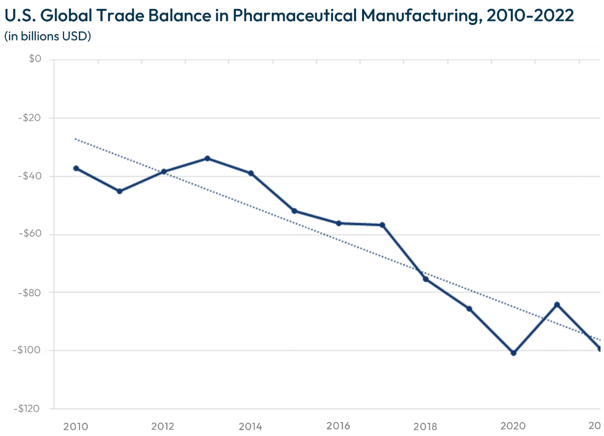
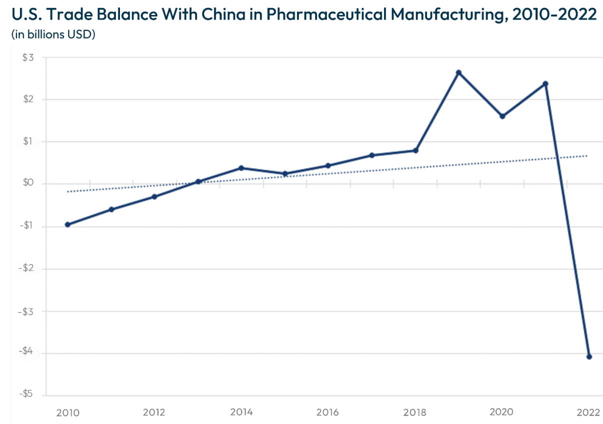
[86] Robert D. Atkinson & Ian Tufts, The Hamilton Index, 2023: China Is Running Away With Strategic Industries, Information Technology & Innovation Foundation (2023).
[87] Niels Graham, The U.S. Is Relying More on China for Pharmaceuticals — and Vice Versa, Atlantic Council (2023).
[88] Niels Graham, The U.S. Is Relying More on China for Pharmaceuticals — and Vice Versa, Atlantic Council (2023).
[89] Testimony of Dr. Janet Woodcock, Director of the Center for Drug Evaluation and Research, Food and Drug Administration, before the House Committee on Energy and Commerce, Subcommittee on Health, "Safeguarding Pharmaceutical Supply Chains in a Global Economy" (2019).
[90] Sandra Barbosu, Not Again: Why the United States Can't Afford to Lose Its Biopharma Industry, Information Technology & Innovation Foundation (2024).





Source: Not Again: Why the United States Can't Afford to Lose Its Biopharma Industry, Information Technology & Innovation Foundation (2024).

In response, U.S. policymakers have designated pharmaceuticals as a critical supply chain priority, committing $40 million to domestic biomanufacturing[91] and an additional $35 million under the Defense Production Act for essential medicines.[92] Although the United States remains a leader in innovation, China's role as a critical supply chain link — reflected in growing U.S. reliance on PRC-origin APIs and widening trade deficits — shows that competition has evolved beyond innovation to encompass the entire pharmaceutical value chain.

Wildcards

- **Could the United States Alter the Biopharma Landscape and Limit Business with PRC Biotechnology Firms?** U.S. policymakers have proposed limiting federal contractors from working with certain PRC biotechnology firms.[93] Though such limitations could initially increase costs and disrupt production, it could strengthen U.S. supply chain security over the longer term.[94] With 79% of U.S. biotechnology firms holding contracts with PRC partners,[95] there is a clear need for diversification. India stands out as a strong alternative given its API production and contract manufacturing expertise,[96] while Japan[97] and South

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[91] Fact Sheet: The United States Announces New Investments and Resources to Advance President Biden's National Biotechnology and Biomanufacturing Initiative, The White House (2022).
[92] Fact Sheet: President Biden Announces New Actions to Strengthen America's Supply Chains, Lower Costs for Families, and Secure Key Sectors, The White House (2023).
[93] H.R.8333, BIOSECURE Act (2024) passed by the U.S. House in September 2024. The Senate companion, S. 3558 failed to pass the Senate.
[94] Elijah Moore, The BIOSECURE Act and Its Impact on U.S. Biopharma Expansion, Site Selection Group (2024).
[95] Trade Association Survey Shows 79% of US Biotech Companies Contract with Chinese Firms, Reuters (2024).
[96] Elijah Moore, The BIOSECURE Act and Its Impact on U.S. Biopharma Expansion, Site Selection Group (2024).
[97] Takeda's Plasma-derived Therapies Manufacturing Facility, Japan, Pharmaceutical Technology (2023).

Korea[98] also offer reliable options. These moves could reduce geopolitical risks and improve the U.S. biopharma sector's long-term resilience.

- **Could China Retaliate Against U.S. Biopharma Firms?** Recognizing the difficulty of immediate derisking, policy proposals to limit business with PRC biotechnology firms, such as the BIOSECURE Act, would allow existing contracts with PRC suppliers to continue until 2032.[99] Enactment of such a proposal could push China to respond aggressively. The PRC's recent restrictions on critical minerals show a willingness to use economic leverage in retaliation.[100] If China were to apply similar tactics to biopharma supplies, U.S. companies might have to accelerate supply chain shifts, incurring high costs and widespread disruption. This highlights the importance of early planning and broader supplier networks.

What to Watch

- **Biomanufacturing Automation Could Eliminate China's Cost Advantage in Production.** Advanced manufacturing technologies like continuous bioprocessing[101] and automated quality control systems[102] could change cost equations in biopharmaceutical production. However, the impact will depend on adoption rates and whether automation can truly offset other cost factors. If widely adopted, these innovations could weaken the cost advantage currently held by PRC manufacturers.

- **AI Tools Could Radically Accelerate Drug Development Timelines.** AI tools are increasingly being deployed across the drug development pipeline,[103] from target identification to clinical trial optimization. This includes advancements in AI-powered simulations, like those being developed in self-driving labs, which can predict the behavior of molecules and accelerate the design process.[104] Both U.S. and PRC companies are making significant investments in AI-enabled drug discovery platforms: as of the first quarter of 2023, 78% of the top 50 investors in AI for drug discovery were based in the United States, with China accounting for around 12%.[105] The technology's actual impact on

[98] Competitive Landscape of Biosimilars in Korea, Aranca (2024).
[99] H.R.8333, BIOSECURE Act (2024).
[100] Amy Lv & Tony Munroe, China Bans Export of Critical Minerals to US as Trade Tensions Escalate, Reuters (2024).
[101] The Cost Efficiency of Continuous Biomanufacturing for First-in-Human Biopharmaceutical Supply, Evotec (2024).
[102] Digitization, Automation, and Online Testing: Embracing Smart Quality Control, McKinsey & Company (2021).
[103] Guadalupe Hayes-Mota, AI Is Rapidly Transforming Drug Discovery, Forbes (2024).
[104] Charles Yang, Self-Driving Labs: AI and Robotics Accelerating Materials Innovation, CSIS (2024); Chris Hubbuch, 'Self-Driving Lab' Speeds Protein Discovery Process, Wisconsin Energy Institute (2024).
[105] Distribution of Leading 50 Investors Involved in AI in Drug Discovery Worldwide as of 2023, by Region, Statista (2023).

development timelines and success rates[106] will be a key metric for assessing future competitive advantages in biopharmaceutical innovation.

- **Localized Bioproduction Could Reduce Dependence on Centralized Global Supply Chains.** Decentralized bioproduction technologies, such as modular biologics manufacturing platforms[107] and single-use bioreactors,[108] could revolutionize the pharmaceutical supply chain by enabling local production. These systems reduce dependency on large, centralized facilities, potentially lessening reliance on China for cost-effective manufacturing. Early adopters of these models may gain a significant edge, especially in responding to global health emergencies or regional shortages.[109] Tracking developments in this space will highlight the players reshaping biopharma production logistics.

Commercial Drones, 2025 Analysis

Assessment: **PRC-Lead**	Confidence Interval: **High**
Direction: **Trend PRC**	Confidence Interval: **High**

China Maintains Lead Amid Rising U.S. Security Concerns

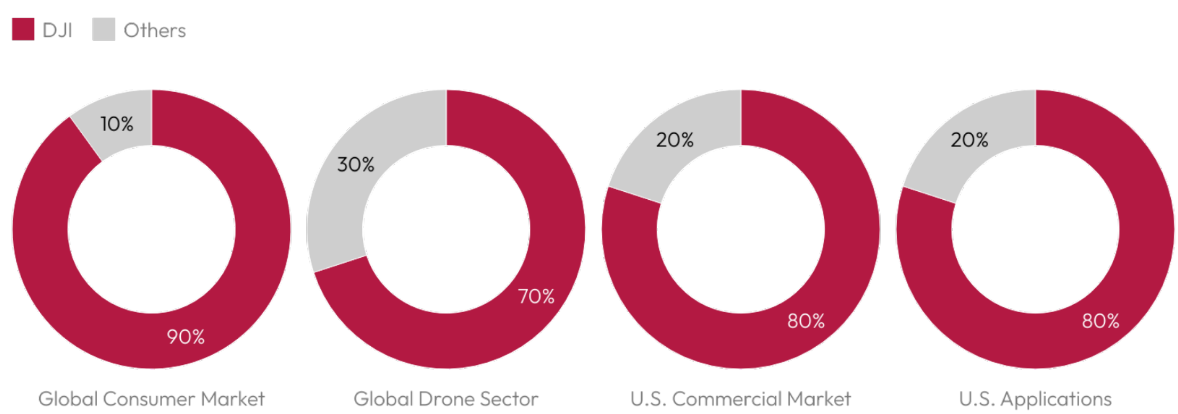
China continues to maintain its substantial lead in the global commercial drone market, with industry leader DJI holding over 90% of the global consumer market[110] and nearly 70% of the overall drone sector,[111] while other companies including Autel continue to gain market share.[112] In the U.S. market alone, DJI holds close to 80% of the commercial segment.[113] This dominance is driven not only by DJI's scale, competitive pricing, and advanced features but also by significant

[106] Sandra Barbosu, Harnessing AI to Accelerate Innovation in the Biopharmaceutical Industry, Information Technology & Innovation Foundation (2024).
[107] Emerging Technologies in Pharmaceutical Manufacturing: Modular and Automated Platforms, Frost & Sullivan (2024).
[108] Jan Kaiserle, Single-Use Bioreactors Plateau, Other Single-Use Tech On the Rise, Biopharma Curated (2024).
[109] Marquerita Algorri, et al., Considerations for a Decentralized Manufacturing Paradigm, International Society for Pharmaceutical Engineering (2023).
[110] Zeyi Yang, Why China's Dominance in Commercial Drones Has Become a Global Security Matter, MIT Technology Review (2024).
[111] Ishveena Singh, The Secret to DJI's Drone Market Dominance: Revealed, DroneDJ (2024).
[112] Gina Chon, DJI Is a More Elusive U.S. Target Than Huawei, Reuters (2021).
[113] Brad Dress, China's Dominant Drone Industry Is a Step Ahead of Congress, The Hill (2024).

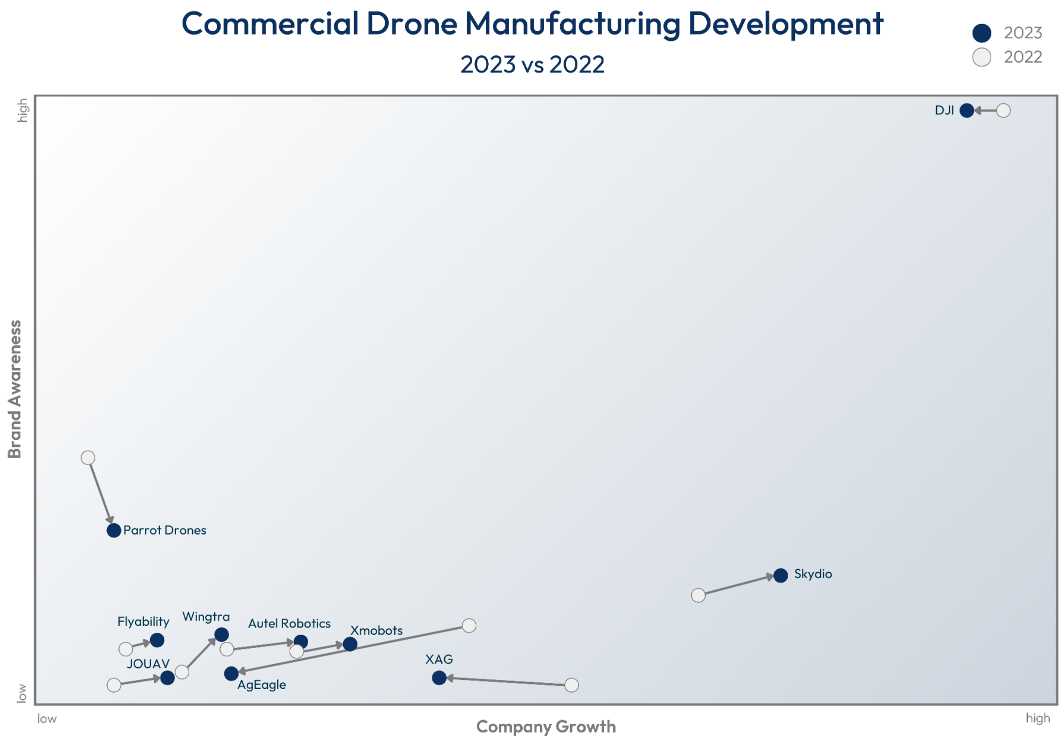
government support,[114] which has strengthened China's drone industry and enabled PRC firms to consistently outperform U.S. competitors. The PRC's stronghold on the commercial drone sector has raised security concerns in the United States, particularly as PRC drones have demonstrated military applications in recent conflicts.[115] Despite various U.S. initiatives to reduce dependency, American drones often remain more expensive, glitch-prone, and challenging to repair than their PRC-made alternatives.[116] As a result, DJI products continue to account for 70 to 90% of drones used across U.S. commercial, government, and consumer applications,[117] leaving China's dominance in the commercial drone supply chain largely unchallenged.

China's Dominance in the Global Drone Market

China's Industry Leader DJI's Market Leadership Across Consumer and Commercial Segments



114 Whitepaper: AUVSI Partnership for Drone Competitiveness, AUVSI Partnership for Drone Competitiveness, (2024).
115 Paul Mozur & Valerie Hopkins, Ukraine's War of Drones Runs Into an Obstacle: China, New York Times (2023; Hannah Beech & Paul Mozur, Drones Changed This Civil War, and Linked Rebels to the World, New York Times (2024).
116 Heather Somerville, Why First Responders Don't Want the U.S. to Ban Chinese Drones, Wall Street Journal (2024).
117 Heather Somerville, Why First Responders Don't Want the U.S. to Ban Chinese Drones, Wall Street Journal (2024).



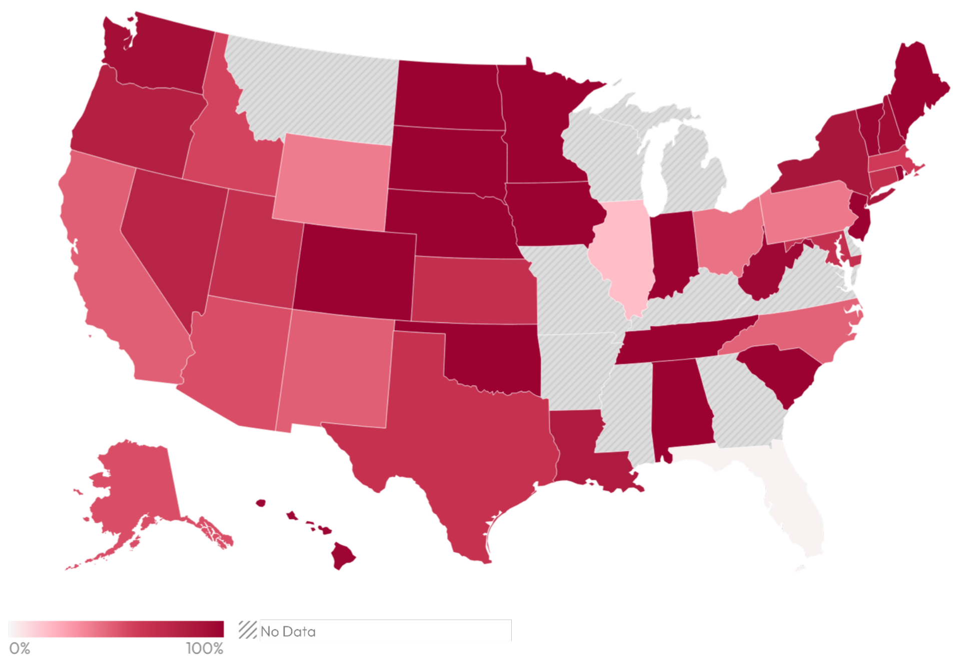
Source: Ed Alvarado, Ranking the Leading Drone Manufacturers, Drone Industry Insights (2023).

In the broader context of the U.S.-China technology competition, the reliance on PRC drones within U.S. government agencies serves as an example of the pervasive dependency on PRC-manufactured drones. From 2010 to 2022, on average 85% of drones purchased by state agencies were PRC-made, underscoring how entrenched this dependency has become at all levels.[118]

[118] Lars Schönander, Securing the Skies: Chinese Drones and U.S. Cybersecurity Risks, Foundation for American Innovation (2023).

Chinese Drone Expenditure Share by U.S. State

Proportion of Total State Drone Spending Allocated to Chinese Drones (2010-2022)



Source: Securing the Skies: Chinese Drones and U.S. Cybersecurity Risks, Foundation for American Innovation (2023).

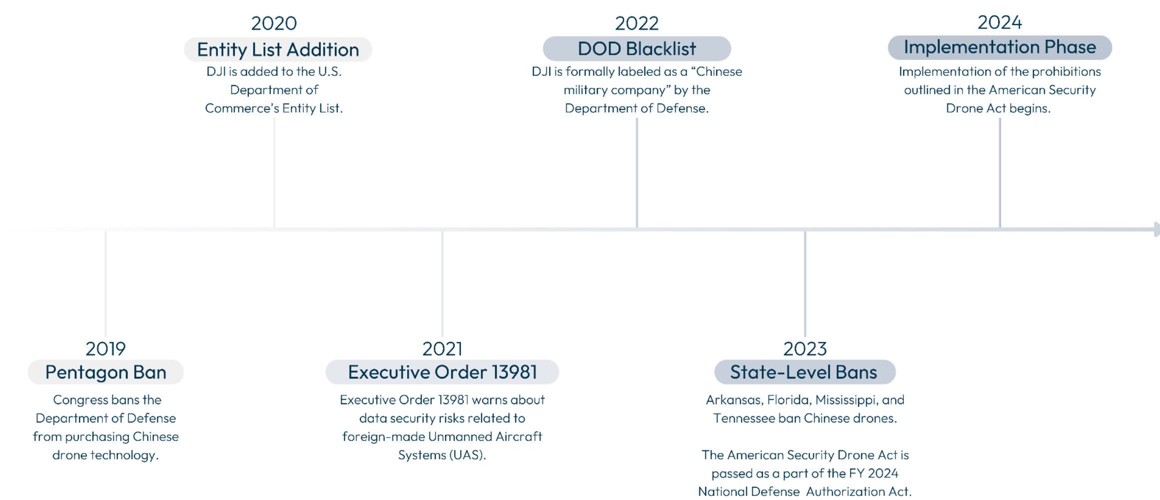
Wildcards

- **Are Market Access Restrictions Enough to Stop China's Drone Dominance?** Since 2017, the U.S. Army has banned PRC-origin drones over security concerns,[119] and the American Security Drone Act of 2023 extended these restrictions to all federal entities.[120] Some agencies, like the Department of the Interior (DOI), allowed limited use of PRC drones for emergencies, but the broader restrictions still disrupted operations.[121] In 2022, the DOI permitted non-emergency use under procurement rules that remain in effect as of 2024, with certain exemptions for critical missions like wildfire management, where alternatives were either too costly or less capable. As the incoming administration considers the trade-offs of restricting or banning the sale of PRC-origin drones, PRC drone manufacturers will

[119] Timeline of U.S. Federal Government Activity Identifying and Addressing Unsecure UAS, Association for Uncrewed Vehicle Systems International (2024); Eric Holdeman, Federal Government Will Require Purchase of 'Made in America' Drones, Government Technology (2024).
[120] American Security Drone Act Of 2023, General Services Administration (last accessed 2024); Gallagher, Colleagues Introduce Bipartisan American Security Drone Act, The Select Committee on the Chinese Communist Party (2023).
[121] Jaron Schneider, U.S. Department of the Interior Says Anti-DJI Regulation Hurt Its Operations, PetaPixel (2024).

likely continue to dominate other markets, barring a breakout domestic supplier or international action.[122]

Timeline of U.S. Government Actions Regarding Commercial Drones



Source: Timeline of U.S. Federal Government Activity Identifying and Addressing Unsecure sUAS, Association for Uncrewed Vehicle Systems International (2024); Lars Erik Schönander, States Push Back Against Chinese Drones, The Hill (2023).

- **Could China's Retaliatory Actions Against U.S. Commercial Drone Companies Accelerate Supply Chain Realignment?** China's recent export controls on U.S. drone companies, which cut off access to essential components like batteries and are forcing U.S. firms to seek alternative suppliers,[123] underscore Beijing's readiness to use supply chain dependencies as leverage amid escalating U.S.-China tensions. PRC actions could stimulate investment in U.S. manufacturing and innovation or push firms to look toward non-PRC sourcing of drone components. Although this alone does not address the technical sophistication and price competitiveness of PRC drones, it could sow the seeds for a potentially building a more resilient and secure domestic supply chain

What to Watch

- **Software and AI Capabilities Will Define the Next Phase of Drone Competition.** The future of competition in commercial drones is likely to move from hardware to software and AI-enabled capabilities, offering the United States an opportunity to leverage its strengths. The United States is beginning to see early wins in the competitive drone

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[122] David Shepardson, US Considers Potential Rules to Restrict or Bar Chinese Drones, Reuters (2025).
[123] Agence France Presse, U.S. Drone Maker Says China Sanctions To Hit Supply Chain, Barron's (2024).

landscape, signaling potential.[124] Nearly 300 U.S.-based drone technology companies have raised approximately $2.5 billion in venture capital since 2022,[125] underscoring strong investor confidence in this sector. As hardware becomes commoditized, advancements in autonomous navigation, AI-driven data processing, and secure data transmission will become essential differentiators. U.S. firms focused on software and cybersecurity may gain a competitive edge by developing secure, decentralized systems for data control, catering to clients prioritizing data privacy and compliance with Western security standards.

- **Taiwan Seeks to Become America's New Production Hub for Drones.** In March 2024, Taiwan's newly elected president affirmed Taiwan's ambitions to become the "Asian center for the democratic drone supply chain," with backing from U.S. partnerships.[126] Taiwan and the United States have been exploring collaborations to reduce reliance on PRC-origin drone components,[127] reflecting lessons learned from Ukraine, where electronic warfare has highlighted the value of AI-driven, resilient drone systems.

- **Swarm Technology Emerges as the Next Frontier in Commercial Drone Applications.** Emerging technologies like swarm capabilities — which enable the coordinated operation of multiple drones — are expected to play a vital role in commercial[128] and defense[129] applications. China has aggressively pursued swarm technology, with field deployments already in progress,[130] while U.S. firms face stricter regulatory controls, potentially impacting their development timelines.

Fifth-Generation Wireless Networks (5G), 2025 Analysis

Assessment: **PRC Lead**	Confidence Interval: **High**
Direction: **Trend PRC**	Confidence Interval: **High**

[124] Heather Somerville, American Drone Startup Notches Rare Victory in Ukraine, Wall Street Journal (2024).
[125] Heather Somerville & Brett Forrest, How American Drones Failed to Turn the Tide in Ukraine, Wall Street Journal (2024).
[126] Joyu Wang, Taiwan Wants a Drone Army — but China Makes the Drones It Wants, Wall Street Journal (2024).
[127] Chris Buckley & Amy Chang Chien, Taiwan and U.S. Work to Counter China's Drone Dominance, New York Times (2024).
[128] Ed Alvarado, Commercial Use of Drone Swarms, Drone Industry Insights (2024).
[129] Zachary Kallenborn, Swarm Clouds on the Horizon? Exploring the Future of Drone Swarm Proliferation, Modern War Institute (2024).
[130] Military and Security Developments Involving the People's Republic of China 2024, U.S. Department of Defense (2024).

China Still Leads in 5G Infrastructure as the United States Works to Overcome Policy Impasses

Despite similar annual capital expenditures of roughly $50 billion by major telecom operators[131][132] China outpaces the United States in 5G infrastructure deployment.[133] With over 4 million base stations reportedly deployed (equating to 206 per 100,000 residents) compared to the United States' approximate 100,000 base stations (77 per 100,000 residents),[134] China has achieved a scale advantage that allows for broader, denser, and more affordable network coverage.[135] China surpassed 1 billion 5G connections in 2024,[136] covering 88% of its mobile users,[137] whereas the United States lags at approximately 45%.[138] Overall download speeds are marginally higher in China at 139 Mbps,[139] compared to 123 Mbps in the United States.[140]

PRC firms like Huawei and ZTE dominate the global exportable hardware market, leveraging competitive pricing, state-backed funding, and rapid deployment to outperform U.S. and allied competitors.[141] China also excels in 5G network processing,[142] integrating advanced hardware capable of managing massive data volumes.[143] Although the United States holds a larger share of wireless spectrum, which is critical for expanding capacity,[144] challenges in spectrum allocation and management have hindered its deployment.[145] Conversely, China has optimized mid-band spectrum use, achieving a balance between coverage and speed.[146] While U.S. providers turn their attention[147] to developing AI-powered advanced networks[148] — including private 5G networks[149]

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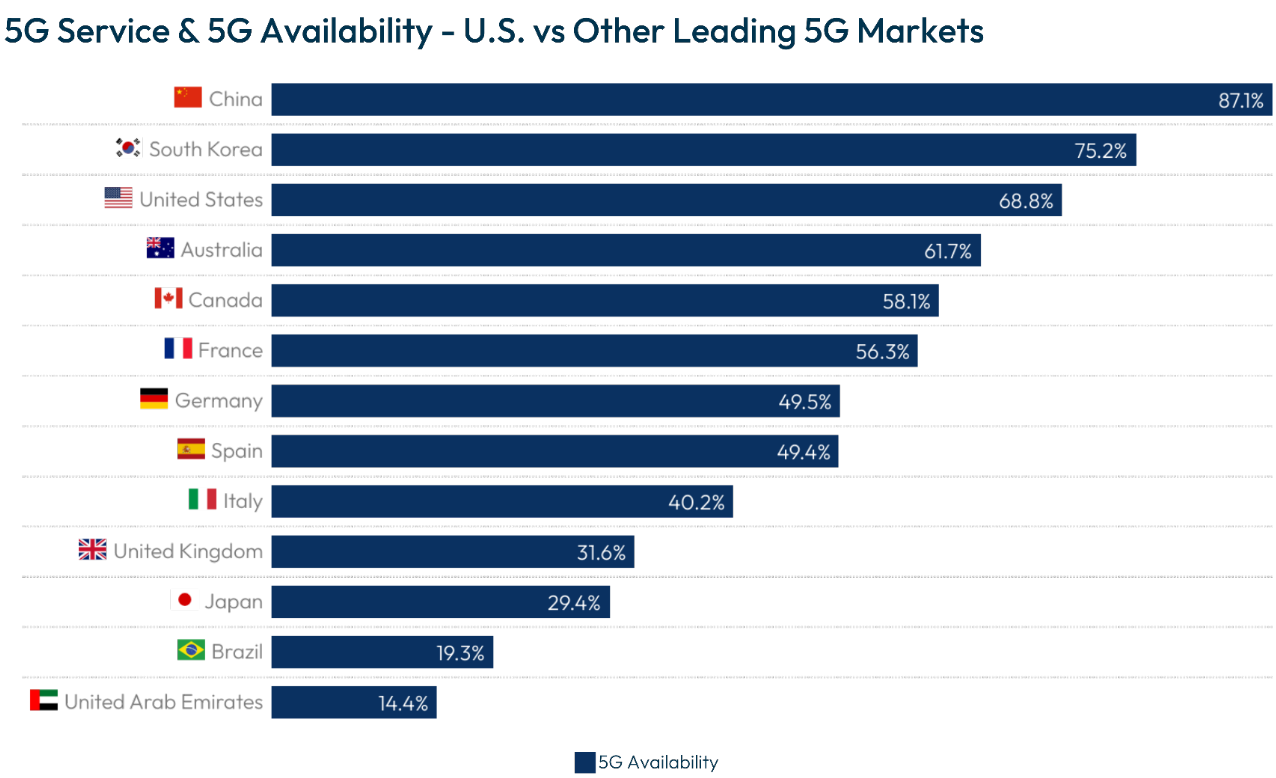
[131] Mike Dano, For 5G Vendors in the US, The Worst May Be Over, Light Reading (2024).
[132] Kenji Kawase, Chinese State Telecoms' 5G Investment Tops Out While Dividends Surge, Nikkei Asia (2024).
[133] Maciej Biegajewsk, Why China Is Winning the 5G Race — And What the West Doesn't Want You to Know!, RFBenchmark (2024).
[134] 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).
[135] Dan Strumpf, U.S. vs. China in 5G: The Battle Isn't Even Close, Wall Street Journal (2020).
[136] China's 5G 'Subs' Climb to 1.15 billion, Telecom TV (2024).
[137] Catherine Sbeglia Nin, China to surpass 1 billion 5G Connections this year, RCR Wireless (2024).
[138] Petroc Taylor, 5G in the United States, Statista (2024).
[139] China's Mobile and Broadband Internet Speeds, Speedtest Global Index (last accessed 2024).
[140] United States's Mobile and Broadband Internet Speeds, Speedtest Global Index (last accessed 2024).
[141] Ngor Luong, Forging the 5G Future: Strategic Imperatives for the US and its Allies, Atlantic Council (2024).
[142] Kitty Wheeler, The Impact of China Unicom & Huawei's 5G-Advanced Network, Technology Magazine (2024).
[143] China Mobile Breaks the Data Processing Bottleneck, Intel (last accessed 2024).
[144] Mark Giles, 5G in the U.S. – Additional Mid-band Spectrum Driving Performance Gains, Ookla (2024).
[145] Ling Zhu, National Spectrum Policy: Interference Issues in the 5G Context, Congressional Research Service (2022).
[146] The U.S. vs. China: The Path to Securing Wireless Leadership, Axios (2024).
[147] Kavit Majitha, Verizon Strategy Boss Turns Attention to 5G-Advanced, Mobile World Live (2022).
[148] The integration of 5G-A and AI, Unleashing Technological Potential and Promoting Industry Innovation, Data Center Dynamics (2024).
[149] Suman Bhattacharyya, Telecom Companies Pin 5G Hopes on Private Industrial Networks, Wall Street Journal (2023).

and edge computing solutions[150] — these efforts remain nascent compared to China's more mature deployment.[151]



Source: 5G in the U.S. — Additional Mid-Band Spectrum Driving Performance Gains, Ookla (2024).

Wildcards

- **Will the U.S. Government Break the 5G Logjam?** The second Trump Administration is expected to restart previous efforts to replace PRC equipment in U.S. and allied networks with trusted alternatives.[152] The Trump Administration's planned deregulatory efforts[153] could extend to easing infrastructure deployment,[154] including for private 5G networks, which will prove decisive in integrating network technologies[155] with emerging IoT applications.[156] In the FY25 National Defense Authorization Act, Congress provided

[150] 5G and Edge Computing: Why Does 5G Need Edge?, STL Partners (last accessed 2024).
[151] Harry Baldock, China Unicom and Huawei Showcase 5G-Advanced with New Beijing Deployment, Total Telecom (2024).
[152] Dean DeChairo, Trump Order Clears Path to Ban Huawei 5G Equipment from United States, Roll Call (2019); Mark Scott, How Trump Won Over Europe on 5G, Politico (2021).
[153] Trump Inc.: How a Second Administration Could Rewrite the Way America Does Business, Wall Street Journal (2024).
[154] Scott Patterson, Trump Pledges to Speed Permitting for Companies Investing Over $1 Billion, Wall Street Journal (2024).
[155] Satyajit Sinha, State of Private 5G in 2024: Key Growth Trends, Use Cases, and Forecast, IoT Analytics (2024).
[156] What is IoT? - Internet of Things Explained, Amazon Web Services (last accessed 2024).

the Federal Communications Commission (FCC) with $3 billion[157] to execute the Trump-signed rip and replace program,[158] which aims to eliminate reliance on PRC communications technology.[159] However, the program remains impeded by years of chronic underfunding[160] and supply chain disruptions.[161] Improved spectrum management, which could support greater network deployment, remains a challenge. Congress has yet to renew the FCC's authority,[162] which lapsed in March 2023, to auction and streamline underutilized government spectrum.[163] The resolution of this legislative bottleneck, while aligning regulatory overhauls with infrastructure rollout, will be pivotal in accelerating 5G progress and ensuring the United States can compete in the global telecommunications race.

- **Will Open RAN Pan Out?** The United States may leverage allied and partner capabilities through strategic partnerships with European telecom operators such as Nokia, Ericsson, and T-Mobile. Although such partnerships are unlikely to close the infrastructure gap with China, they could bolster domestic 5G infrastructure while enhancing capabilities in advanced network technologies like Open Radio Access Network (RAN)[164] and AI-driven network management.[165] Open RAN has generated excitement for its ability to allow operators to mix and match hardware and software components from multiple vendors, while diversifying supply chains and being cost effective.[166] As the technology is still maturing,[167] it is facing concerns about its performance, security, and integration, thereby slowing deployment.[168] Furthermore, China's investments in proprietary alternatives and its influence in emerging markets through cost-effective turnkey solutions[169] challenge[170] Open RAN's global adoption.[171] While the United States and allies grapple with Beijing's increasing subterfuge of the

[157] H.R. 5009, Servicemember Quality of Life Improvement and National Defense Authorization Act for Fiscal Year 2025 at Sec. 5404(c) (2024); Eduard Kovacs, 2025 NDAA Provides $3 Billion Funding for FCC's Rip-and-Replace Program, SecurityWeek (2024).
[158] President Signs Rip and Replace Bill Into Law, U.S. Senate Committee on Commerce, Science, & Transportation (2020).
[159] Jill C. Gallagher, Secure and Trusted Communications Networks Reimbursement Program: Frequently Asked Questions, Congressional Research Service (2023).
[160] Jake Neenan, Rip-and-Replace Continues to Feel Funding Shortfall, FCC Says, Broadband Breakfast (2024).
[161] Nicole Ferraro, FCC approves more 'rip-and-replace' extensions due to supply chain, Light Reading (2024).
[162] Patricia Moloney Figliola & Jill C. Gallagher, The Federal Communications Commission's Spectrum Auction Authority: History and Options for Reinstatement, Congressional Research Service (2023).
[163] Monica Alleven, AT&T Says It's Not Getting 'Windfall' from 4.9 GHz Spectrum, Fierce Network (2024).
[164] Explore Open RAN: Innovation and Flexibility, Ericsson (last accessed 2024).
[165] Dan Jones, T-Mobile Readies 5G-Advanced Launch at 'The End of the Year', Fierce Network (2024).
[166] Chair Latta Opening Remarks on Strengthening American Communications Leadership with Open Radio Access Networks, U.S. House Committee on Energy & Commerce (2024).
[167] O-RAN: Challenges and Prospects on the Road to Maturity, LitePoint (2023).
[168] The Opportunities and Challenges of Open RAN: What it Means for the Future of Telecom, RCR Wireless (2024).
[169] Manoj Harjani, O-RAN is Overhyped as Avoiding Chinese 5G Influence, Australian Strategic Policy Institute (2024).
[170] Iain Morris, How Huawei and Open RAN Misfires Hurt Ericsson, Nokia and Telcos, Light Reading (2024).
[171] Chris Antilitz, Open RAN Adoption in 2024, TBR Insight Center (2024).

global telecommunications infrastructure,[172] Open RAN's success will depend on overcoming technical maturity issues, ensuring interoperability, leveraging allied capabilities, and addressing security considerations[173] to provide competitive alternatives, particularly in price-sensitive regions.

What to Watch

- **Step-Changes to 5G Architectures May Spur New Commercial Applications.** The integration of AI into advanced networks is poised to define the next phase of 5G competition. The lack of compelling commercial use cases has so far hindered widespread adoption of 5G in the United States.[174] However, the convergence of AI with 5G networks[175] has the potential to drive adoption by unlocking new applications across sectors such as agriculture,[176] manufacturing,[177] and defense.[178] These emerging use cases could partially offset infrastructure gaps and position the United States to capitalize on its strengths in AI and software innovation. As China makes strides[179] in network slicing technology[180] — a capability critical for industrial IoT — the United States may leverage its strengths in AI, software, and cloud services to accelerate the rollout of private 5G networks and 5G RedCap (Reduced Capability), designed for IoT applications requiring lower power and cost.[181] Addressing existing security concerns around Open RAN could potentially reshape the competitive landscape by reducing reliance on single-vendor solutions and diversifying global supply chains.

- **The Ongoing Battle for Influence over 6G Standards.** Although 6G networks are not expected until 2030,[182] the development of technical standards for 6G will be a pivotal battleground.[183] In September 2024, the International Telecommunication Union (ITU) adopted[184] three 6G standards proposed by the Chinese Academy of Sciences[185] and

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[172] Dustin Volz, Dozens of Countries Hit in Chinese Telecom Hacking Campaign, Top U.S. Official Says, Wall Street Journal (2024).
[173] Open Radio Access Networks Security Considerations, Cybersecurity and Infrastructure Security Agency (2024).
[174] The Challenge of Monetizing 5G, PwC (2023).
[175] Baris Kavakli, Why 5G needs AI: A Technology-Driven Revolution Lacking Initial User Demand, Portera (2024).
[176] How 5G Networks Support Precision Agriculture, Avnet (2023).
[177] Dan Omalley, 5G in Manufacturing: The Key to Industry 4.0, NYBSYS (2024).
[178] Leland Brown & Stan Mo, How to Combine 5G networks, Artificial Intelligence to Aid Warfighters, C4ISR (2022).
[179] Joe Madden, Network Slicing is Alive in China, Fierce Network (2022).
[180] Kinza Yasar & John Burke, What is Network Slicing?, Tech Target (2024).
[181] What is 5G RedCap? Exploring Benefits and Use Cases, Telenor IoT (last accessed 2024).
[182] Arjun Kharpal, Tech Next-Gen Mobil Internet — 6G — Will Launch in 2030, Telecom Bosses Say, Even as 5G Adoption Remains Low, CNBC (2023).
[183] Ananmay Agarwal, The Silent Struggle: How Technical Standards Shape Global Tech Power, Special Competitive Studies Project (2024).
[184] Rimjhim Singh, China's ITU-Approved 6G Standards Set Stage for Advanced Telecom Solutions, Business Standard (2024).
[185] Cole McFaul et. al, Fueling China's Innovation: The Chinese Academy of Sciences and Its Role in the PRC's S&T Ecosystem, Center for Security and Emerging Technology (2024).

China Telecom. While China's dominance in 5G infrastructure positions it favorably for shaping future standards, the United States is collaborating with allies and partners to develop shared principles for 6G.[186] As the 5G race moves into its next phase and the groundwork for 6G is laid, technological advancements, strategic partnerships, and the ability to shape standards will determine long-term leadership in the global telecommunications ecosystem.

Fusion Energy, 2025 Analysis

Assessment: **U.S.-Lead**	Confidence Interval: **High**
Direction: **Trend Contested**	Confidence Interval: **Low**

The U.S. Lead in Fusion Energy is Narrowing

The fusion energy competition between the United States and China is more contested than ever before. While the United States still benefits from cutting-edge research and robust industry investment, China is moving rapidly to close the gap. The Lawrence Livermore National Laboratory's (LLNL) National Ignition Facility (NIF) achieved a historic milestone in December 2022 by producing more energy from fusion than was put into the reaction[187] — an achievement hailed as "one of the most significant scientific achievements of the 21st century."[188] This breakthrough, consistently reproduced[189] and unmatched by any other nation, marks a pivotal step toward commercial fusion energy. Recent progress in AI, physics, and applied science has broadened the U.S. fusion ecosystem beyond national labs, with 25 of the world's 45 active fusion companies based in the United States, collectively raising over $6 billion of the $8 billion[190] in total global private fusion investment. In contrast, China's three known fusion companies have secured a combined $580 million.[191]

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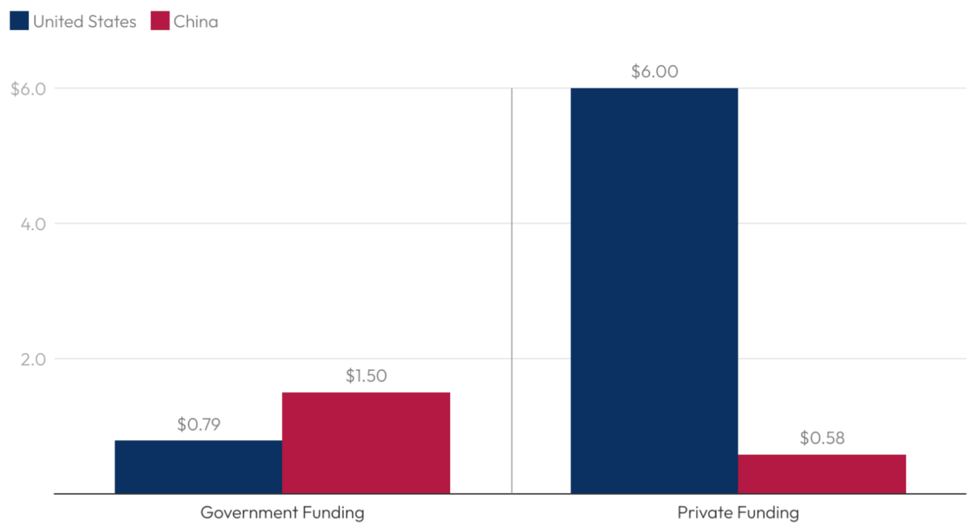
[186] Joint Statement Endorsing Principles for 6G: Secure, Open, and Resilient by Design, The White House (2024).
[187] Breanna Bishop, Lawrence Livermore National Laboratory Achieves Fusion Ignition, Lawrence Livermore National Laboratory (2022).
[188] Jeremy Thomas, A Shot for the Ages: Fusion Ignition Breakthrough Hailed as 'One of the Most Impressive Scientific Feats of the 21st Century', Lawrence Livermore National Laboratory (2022).
[189] Jeff Tollefson, U.S. Nuclear-Fusion Lab Enters New Era: Achieving 'Ignition' Over and Over, Nature (2023).
[190] 2024 Global Fusion Industry Report, Fusion Industry Association (2024).
[191] 2024 Global Fusion Industry Report, Fusion Industry Association (2024).

Government vs Private Fusion Funding: U.S. and China
(in billions USD)



U.S. government funding for fusion does not include the funding designated for fusion activities under the National Nuclear Security Administration (NNSA).

China's commitment to catching up is evident in its strategic approach[192] to government funding in fusion energy, which mimics[193] U.S. development plans,[194] national laboratory models, and company strategies.[195] Although the U.S. Department of Energy's (DOE) Fusion Energy Sciences (FES) budget reached $790 million in FY2024,[196] Beijing invests nearly twice that amount — about $1.5 billion annually – though gaining a detailed understanding of PRC government spending can be elusive.[197] Additionally, while these funding comparisons appear straightforward, the distinction between government and private sector investment in China is often less clear-cut than in the United States because many PRC companies maintain close state ties, align with national priorities, and receive significant state funding. China is focused on commercialization by directing most of its funding toward facilities that can compete with leading U.S. private companies.[198] Much of U.S. fusion spending, on the other hand, supports legacy programs rather

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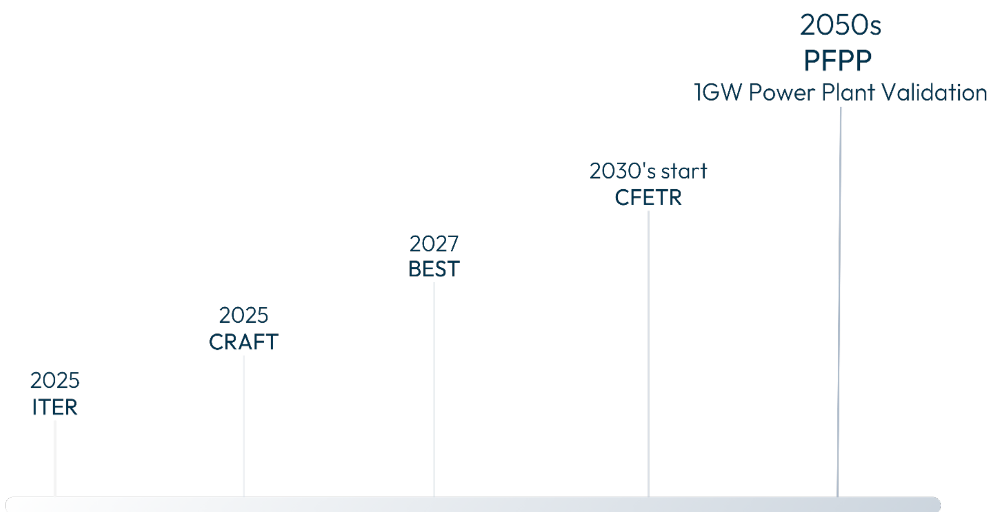
[192] Losing the Race for Nuclear Fusion, Special Competitive Studies Project (2024).
[193] Opening Statement of Chairman Joe Manchin, before the Senate Energy and Natural Resources Committee, Full Committee Hearing to Examine Fusion Energy Technology Development (2024).
[194] Powering the Future: Fusion & Plasmas, Fusion Energy Sciences Advisory Committee (2020).
[195] Angela Dewan & Ella Nilsen, The U.S. Led on Nuclear Fusion for Decades. Now China Is in Position to Win the Race, CNN (2024).
[196] Congress Increases U.S. Funding for Fusion Energy Sciences Research, Fusion Industry Association (2024).
[197] Jean Paul Allain, Building Bridges: A Bold Vision for the DOE Fusion Energy Sciences, Office of Science for Fusion Energy Sciences (2023).
[198] Jennifer Hiller & Sha Hua, China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail, Wall Street Journal (2024).

than cutting-edge development[199] and nearly one-third of the annual FES budget[200] goes to the delayed International Thermonuclear Experimental Reactor (ITER) project in France.[201]

China is already translating its funding and commercialization focus into action, constructing infrastructure that spans every stage of fusion development.[202] The Experimental Advanced Superconducting Tokamak (EAST) supports advanced research, while the Comprehensive Research Facility for Fusion Technology (CRAFT)[203] and the Burning Experimental Superconducting Tokamak (BEST)[204] drive development efforts. The China Fusion Engineering Test Reactor (CFETR)[205] serves as a demonstration platform, all leading toward a future gigawatt-scale power plant. By contrast, the United States excels at research but relies more on private companies for development and demonstration, with no national deployment facility planned. China's integrated approach may allow it to move more quickly toward full-scale commercial fusion power.

Chinese Fusion Roadmap



Source: Jean Paul Allain, Building Bridges: A Bold Vision for the DOE Fusion Energy Sciences, U.S. Department of Energy (2023).

[199] Jennifer Hiller & Sha Hua, China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail, Wall Street Journal (2024).
[200] The Current U.S. Approach to Fusion, Special Competitive Studies Project (2024).
[201] Elizabeth Gibney, ITER Delay: What It Means for Nuclear Fusion, Nature (2024).
[202] Testimony of Patrick White, before the U.S. Senate Committee on Energy and Natural Resources, Full Committee Hearing to Examine Fusion Energy Technology Development (2024).
[203] Victoria Bela, China Launches 'Kuafu' Nuclear Fusion Research Facility, Named After Mythical Giant, in Quest to Build 'Artificial Sun', South China Morning Post (2023).
[204] China New Growth: Controlled Nuclear Fusion Emerges as New Frontier for China's Venture Capitalists, Xinhua (2024).
[205] Research, Institute of Plasma Physics, Chinese Academy of Sciences (last accessed 2024).

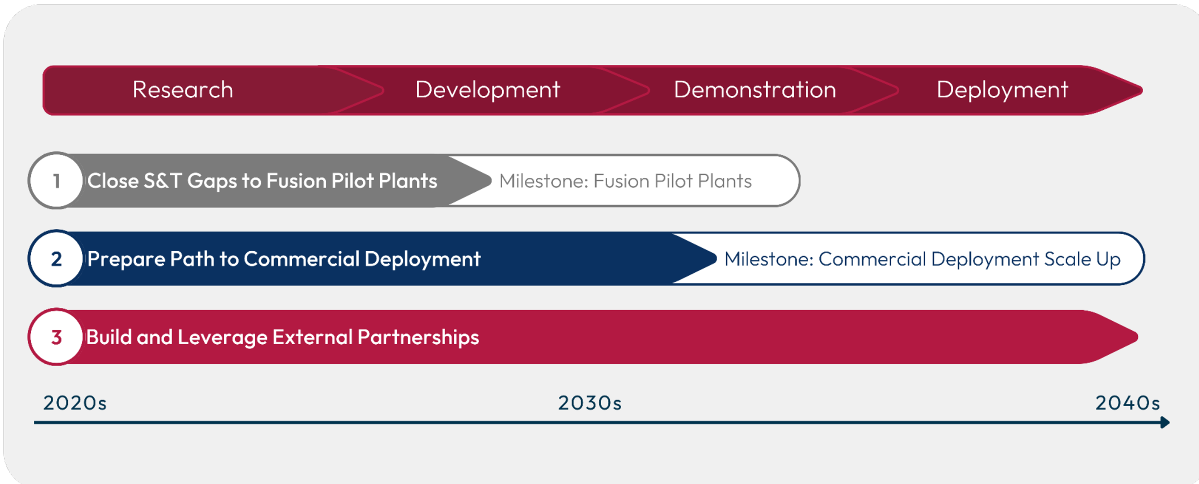
Beyond infrastructure, China's human capital and intellectual property advantages add to its momentum. It produces ten times as many Ph.D.s in fusion science and engineering as the United States[206] and surpassed American fusion technology patent application filings in 2023.[207] Its fusion workforce operates with remarkable efficiency, keeping facilities running nearly nonstop. Experts predict that at this rate, China could overtake U.S. and European magnetic fusion capabilities within three to four years.[208] Although the United States leads in foundational research and total private investment, breakthroughs alone may not preserve that lead. Achieving commercial fusion requires coordinated efforts that bridge the gap between laboratory success and scalable power plants — an area where China's comprehensive, state-backed strategy may ultimately give it the upper hand.

Wildcards

- **Will New Federal Programs Bridge the Public-Private Development Gap?** Building on the 2022 Bold Decadal Vision,[209] recent U.S. initiatives aim to push fusion toward commercialization. The DOE's 2024 Fusion Energy Strategy focuses on three pillars: bridging technological gaps for a pilot plant, enabling sustainable deployment, and forging external partnerships.[210] It identifies near-term challenges in the 2020s (capital flow, materials, regulations), mid-term issues in the 2030s (infrastructure and supply chains), and large-scale hurdles in the 2040s.[211] New efforts like the $45 million FIRE Collaboratives[212] provide testing infrastructure that private firms cannot develop on their own, while the Milestone-Based Fusion Development Program seeks to reduce investment risk.[213] However, spending lags behind authorized funds,[214] and two forthcoming developments — the DOE's 2025 commercialization roadmap[215] and the ADVANCE Act's potential licensing reforms[216] — could either accelerate progress or introduce new uncertainties.

[206] Jennifer Hiller & Sha Hua, China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail, Wall Street Journal (2024).
[207] Rimi Inomata, China Tops Nuclear Fusion Patent Ranking, Beating U.S., Nikkei Asia (2023).
[208] Jennifer Hiller & Sha Hua, China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail, Wall Street Journal (2024).
[209] Readout of the White House Summit on Developing a Bold Decadal Vision for Commercial Fusion Energy, The White House (2022).
[210] Fusion Energy Strategy 2024, U.S. Department of Energy (2024).
[211] Fusion Energy Strategy 2024, U.S. Department of Energy (2024).
[212] DOE Science FY24 Final Appropriation Excerpt, U.S. Department of Energy (2024).
[213] Department of Energy Announces $50 Million for a Milestone-Based Fusion Development Program, U.S. Department of Energy (2022).
[214] DOE Announces $46 Million for Commercial Fusion Energy Development, U.S. Department of Energy (2023).
[215] Fusion Energy Strategy 2024, U.S. Department of Energy (2024).
[216] U.S. Senate Passes ADVANCE Act, Including Legislation to Codify US Fusion Regulations, Fusion Industry Association (2024).

DOE Fusion Strategy Supporting the U.S. Bold Decadal Vision



Source: Fusion Energy Strategy 2024, U.S. Department of Energy (2024).

- **How Will China's Supply Chain Control Impact U.S. Fusion Progress?** China is expanding its influence beyond research advances, positioning it to control portions of the fusion supply chain by securing critical materials and components.[217] Although the U.S. currently excels in some technologies (lasers, superconductors, software), China's dominance in rare earths, high-quality manufacturing, and mass production is poised to create vulnerabilities for American firms – particularly given uncertain long-term demand signals and a shortage of skilled workers.[218] This strategic approach mirrors its success in solar panels and electric vehicle batteries,[219] potentially limiting the United States' ability to scale fusion engineering breakthroughs into commercial reactors. While new DOE programs and regulatory reforms may speed U.S. development, true leadership in fusion will also require securing supply chains — a lesson reinforced by China's track record of leveraging control over critical minerals to shape entire industries.

What to Watch

- **AI Technologies Accelerate Critical Breakthroughs in Fusion Development.** AI is emerging as a powerful tool in fusion, enabling both the United States and China to push beyond conventional trial-and-error approaches. The United States is applying AI across

[217] Aaron Larson, U.S. in a Race with China to Develop Commercial Fusion Power Technology, POWER (2024).
[218] Angela Dewan & Ella Nilsen, The U.S. Led on Nuclear Fusion for Decades. Now China Is in Position to Win the Race, CNN (2024).
[219] You Xiaoying, The 'New Three': How China Came to Lead Solar Cell, Lithium Battery, and EV Manufacturing, Dialogue Earth (2023).

multiple fronts: Google's advanced AI systems enhance reactor efficiency,[220] Princeton Plasma Physics Laboratory's AI platforms predict and prevent plasma instabilities in real time,[221] and LLNL's cognitive simulation methods helped achieve fusion ignition by optimizing experimental designs.[222] China has also harnessed AI, using neural networks trained on extensive plasma data sets to improve measurement speeds by a factor of ten.[223] These advances, coupled with sophisticated modeling and simulation environments like the Idaho National Laboratory's MOOSE and FENIX frameworks, can accelerate learning, tackle persistent engineering challenges,[224] and ultimately bring fusion closer to commercial reality.

- **Nuclear Infrastructure Development Shapes the Path to Fusion Commercialization.** As fusion moves toward commercialization, existing nuclear infrastructure provides a strategic advantage.[225] China's rapidly expanding nuclear industry leads the world in conventional reactor construction, with 22 of the 58 reactors under development globally and the first Small Modular Reactor (SMR) now in commercial operation.[226] In contrast, the United States faced hurdles in building new reactors[227] and, as of August 2024, had none under construction.[228] However, in November 2024, the U.S. Nuclear Regulatory Commission approved the first Generation IV power-producing reactor authorized for construction in the country.[229] The presence or absence of supporting nuclear infrastructure could influence how quickly each nation transitions from demonstration to deployment of fusion power.

- **International Partnerships Emerge as Key Differentiators in Fusion Competition.** Global alliances are becoming increasingly important in shaping fusion's future.[230] Recent

[220] Pulsar Team & Swiss Plasma Center, Accelerating Fusion Science Through Learned Plasma Control, Google DeepMind (2022).
[221] Jaemin Seo, et al., Avoiding Fusion Plasma Tearing Instability with Deep Reinforcement Learning, Nature (2024).
[222] Jeremy Thomas, High-Performance Computing, AI and Cognitive Simulation Helped LLNL Conquer Fusion Ignition, Lawrence Livermore National Laboratory (2023).
[223] Aman Tripathi, China Achieves Fusion Milestone with 10x Improvement in Plasma Measurement Speed, Interesting Engineering (2024).
[224] Pierre-Clément Simon & Casey Icenhour, Developing the Future of Fusion Energy, Federation of American Scientists (2024).
[225] Stephen Ezell, How Innovative Is China in Nuclear Power?, Information Technology & Innovation Foundation (2024).
[226] Sha Hua, Atomic Power Is In Again—and China Has the Edge, Wall Street Journal (2023).
[227] William Mauldin & Jennifer Hiller, Washington Heats Up Nuclear Energy Competition With Russia, China, Wall Street Journal (2024).
[228] Safely and Responsibly Expanding U.S. Nuclear Energy: Deployment Targets and a Framework for Action, The White House (2024).
[229] Sonal Patel, NRC Approves Construction of First Electricity-Producing Gen IV Reactor in the U.S., Power (2024).
[230] International Partnerships in a New Era of Fusion Energy Development, The White House (2023).

U.S. partnerships with the United Kingdom[231] and Japan[232] focus on sharing facilities, harmonizing regulations, and bolstering supply chain resilience—moves that could offset China's tightly integrated domestic ecosystem. These collaborations aim to accelerate progress, reduce costs, and maintain leadership as the window for securing a dominant position narrows. Without timely, coordinated action, the United States risks ceding ground in the race to commercialize what may become the defining energy technology of the century.

Internet Platforms (Social Media/Mobile Operating Systems), 2025 Analysis

Assessment: **U.S.-Lead**	Confidence Interval: **Moderate**
Direction: **Trend Contested**	Confidence Interval: **Moderate**

The United States Leads But New PRC Platforms Are Catching Up

Overall, U.S. Internet platforms maintain a lead in terms of overall market capitalization, and the majority of the global population uses them to connect, communicate,[233] and find information.[234] U.S.-based social media companies held the top four spots in monthly active users worldwide as of July 2024,[235] and Google had roughly 90% of the global search engine market share in November 2024.[236] But the steady emergence of new PRC mobile applications onto the global stage over the past two years, coupled with the Chinese Communist Party's (CCP) increasing calls for self-reliance in both hardware and software, have shifted our outlook.

[231] Joint Statement Between DOE and the UK Department for Energy Security and Net Zero Concerning a Strategic Partnership to Accelerate Fusion, U.S. Department of Energy (2023).
[232] Joint Statement Between DOE and the Japan Ministry of Education, Sports, Science and Technology Concerning a Strategic Partnership to Accelerate Fusion Energy Demonstration and Commercialization, U.S. Department of Energy (2024).
[233] Global Social Media Statistics, Global Digital Insights (last accessed 2024).
[234] Search Engine Market Share Worldwide, GlobalStats (2024).
[235] Most Popular Social Networks Worldwide as of April 2024, By Number of Monthly Active Users, Statista (2024).
[236] Search Engine Market Share Worldwide, GlobalStats (2024).

The emergence and meteoric rise of new PRC Internet platforms[237] — particularly Bytedance's TikTok, one of the top social media applications among the youth demographic in North America, second only to Youtube[238] — shows that China's success in this sector was not a fluke, but rather the beginning of a larger trend. Capcut, a video editing tool, also a product of Bytedance, became the fifth most popular app in 2023.[239] PRC e-commerce apps, such as Temu and Shein, have skyrocketed in popularity among global Internet users. Notably, Temu, whose parent company is TDD Holdings, now sits among the top ten most popular apps in 2023.[240] Even new PRC AI startups, like Moonshot.ai and Minimax, have gained a sizable following in the United States, with Minimax's AI chat app "Talkie" boasting 11.4 million monthly active users.[241]

Most Popular Apps by Download, 2023

Rank	Country of Origin	Mobile App	Parent Company
1		Instagram	Meta
2		**TikTok**	**ByteDance**
3		Facebook	Meta
4		WhatsApp	Meta
5		**CapCut**	**ByteDance**
6		Telegram	Telegram
7		Snapchat	Snap
8		**Temu**	**PDD Holdings**
9		WhatsApp Business	Meta
10		Spotify	Spotify

Source: David Curry, Most Popular Apps (2024), Business of Apps (2024).

Wildcards

- **Will U.S. Policy Changes Finally Address the Market Access Imbalance with China?** One of the biggest imbalances in this space is that virtually all U.S. Internet platforms are

[237] Mapping the U.S.-PRC Tech Competition Landscape, Special Competitive Studies Project (2023).
[238] Monica Anderson, et al., Teens, Social Media and Technology 2023, Pew Research Center (2023).
[239] David Curry, Most Popular Apps (2024), Business of Apps (2024).
[240] David Curry, Most Popular Apps (2024), Business of Apps (2024).
[241] Paul Triolo & Kendra Schaefer, China's Generative AI Ecosystem in 2024: Rising Investment and Expectations, The National Bureau of Asian Research (2024).

barred from operating in the PRC market, while PRC platforms are able to operate freely in the United States — at least for now. That is likely to change, as the U.S. government is beginning to implement policies aimed at limiting the influence of PRC Internet platforms within its borders. The White House, for example, recently announced a new proposal that would eliminate a customs loophole that Shein and Temu have exploited to import millions of dollars' of low-value items into the United States tariff-free.[242]

- **Could TikTok's Fate Reshape the Future of PRC-Developed Apps in America?** The saga of Tiktok, which is facing potential divestment or a ban in early 2025, underscores the escalating scrutiny and uncertainty surrounding PRC-owned Internet platforms in the United States.[243] However, recent signals from the incoming administration suggest a softened stance toward TikTok, with incoming president Trump indicating that a complete ban may no longer be a foregone conclusion.[244] This shift in policy highlights the evolving dynamics in the debate over PRC technology in the United States and the broader challenges of isolating a PRC-origin mobile application from the U.S. tech ecosystem, especially after it has established such a significant domestic user base. This case and the precedent that the ruling will set could have far-reaching implications for other PRC apps operating in the United States.

What to Watch

- **Huawei Advances China's Mobile Operating System Independence.** China's Huawei is making a play to build an alternative mobile application ecosystem, a space long dominated by Apple's App Store and Google's Play Store. Previous versions of Huawei's mobile operating system were based on open-source Android and operated on a Linux kernel. In November 2024, however, Huawei launched its first smartphones[245] with the capability to run its indigenously-developed "pure blood" mobile operating system.[246]

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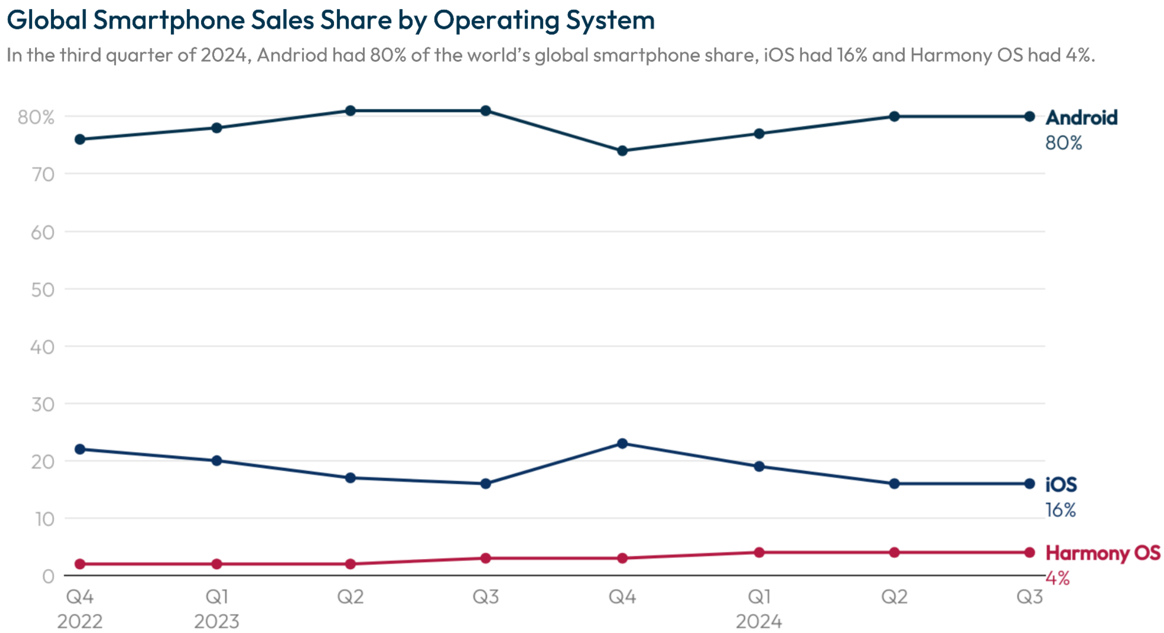
[242] Annie Nova & Gabrielle Fonrouge, Biden Targets Shein, Temu with New Rules to Curb Alleged 'Abuse' of U.S. Trade Loophole, CNBC (2024).
[243] Dan Primack, TikTok "Ban Bill" Heads to Court, Axios (2024).
[244] Trump Signals Openness to Stopping TikTok Ban, Softening Stance, Bloomberg (2024).
[245] Arjun Kharpal, Huawei Launches First Phones Capable of Running its New Self-Developed Operating System, CNBC (2024).
[246] Marco Lancaster, HarmonyOS NEXT Launches This Month Without Android, GizChina (2024).



Source: Global Smartphone Sales Share by Operating System , Counterpoint Research (2024).

The new operating system is reportedly built with completely indigenous code, independent from open-source Android. Huawei's existing mobile operating system, HarmonyOS, recently overtook Apple's iOS as being the second most used mobile operating system in China, after Android.[247] Currently, about 700 million devices run on HarmonyOS and 2.2 million third-party developers are creating apps for the platform,[248] with Huawei aiming to build over 100,000 applications for the operating system within the next year.[249] Notably, the Huawei app storefront on these devices has an emulator that allows them to run Android-based apps, a feature that may be particularly tailored for Chinese citizens working abroad.[250] However, HarmonyOS NEXT has a long road ahead before it may pose as a serious competitor to Apple and Google, but its development will be a noteworthy milestone in addressing one of China's long-perceived gaps in mobile operating systems, a key vulnerability identified by a prominent PRC think tank report in 2022 that was subsequently censored.[251]

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[247] Iris Deng, Huawei's HarmonyOS Unseats Apple's iOS to Become China's No 2 Mobile Operating Platform, South China Morning Post (2024).
[248] Lionel Lim, Huawei's Homegrown Operating System, Launched After the Company Was Put on a U.S. Blacklist, May Soon Overtake Apple's iOS in China, Fortune (2024).
[249] Juliana Liu & Hassan Tayir, Huawei's New Homegrown Chinese Smartphone Takes on Apple and Android, CNN (2024).
[250] Alan Friedman, Surprise! Huawei's HarmonyOS NEXT Can Run Android Apps, Phone Arena (2024).
[251] Jeff Pao, Academic Report Unveils China's High-Tech Bottlenecks, Asia Times (2022).

Next-Generation Networks (Low Earth Orbit Satellites), 2025 Analysis

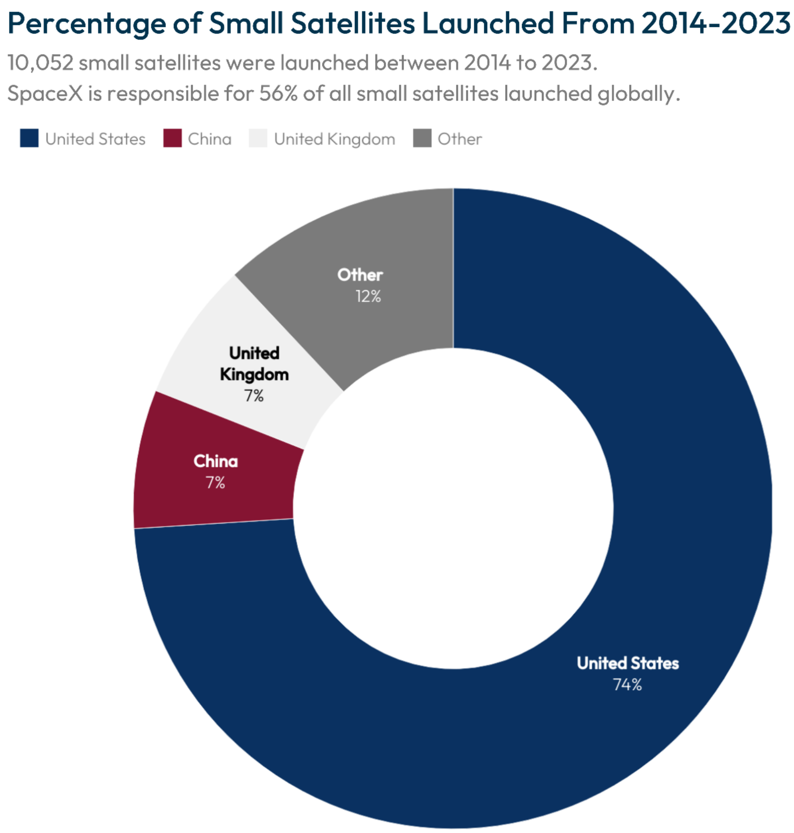
Assessment: **Contested**	Confidence Interval: **Moderate**
Direction: **Trend U.S.**	Confidence Interval: **Moderate**

The United States is Making Early Wins in the Path to Future Networks

Non-terrestrial networks (NTNs)[252] will be key to fostering next-generation networks and a critical piece is low-earth orbit (LEO) satellites. To date, the United States holds a commanding lead in the deployment of LEO satellite constellations, with U.S. company, Starlink, having deployed approximately 6,764 LEO satellites.[253] Other U.S. and allied companies such as London-based OneWeb and Amazon's Project Kuiper, have plans to launch more in the next year.[254] U.S. companies like Starlink[255] and AST SpaceMobile are also taking a global lead in D2D-enabled (direct to device) satellites, which reduce implementation costs via decreased need for the base stations that traditionally serve as interlocutors between LEO satellites and terrestrial networks.[256] As of 2024, Starlink has about 300+ LEO satellites in operation and users can now access the beta version and experience D2D enabled networks themselves.[257] Despite Beijing's strategic prioritization of space technologies, via quantum communications,[258] and earlier this year, a successful space mission to the other side of the moon, China is lagging behind in the deployment of LEO mega-constellations.[259] This past August, Beijing launched a series of 18 LEO

[252] Low-earth orbit (LEO) satellites are part of a broader non-terrestrial satellite (NTN) ecosystem that includes medium-earth orbit (MEO) and geostationary orbit (GEO) satellites, MEOs and GEOs both complement LEOs with capabilities like balanced coverage, latency for underserved areas, and high-capacity broadcasting for fixed locations. High-altitude platforms (HAPS), such as solar-powered drones and stratospheric balloons, provide localized connectivity and disaster recovery in remote areas. NTNs are also advancing into lunar and interplanetary communications through optical and quantum technologies, promising to revolutionize global connectivity, bridge digital divides, and enable next-generation services.
[253] Tereza Pultarova & Elizabeth Howell, Starlink Satellites: Facts, Tracking and Impact on Astronomy, Space News (2024).
[254] Everything you need to know about Project Kuiper, Amazon's satellite broadband network, Amazon (Last Accessed 2024)
[255] Rachel Jewett, SpaceX Now Has More Than 100 Direct-to-Cell Satellites in Orbit, Via Satellite (2024).
[256] Mike Robuck, A Lot of People Want to be in AST SpaceMobile's Orbit, Mobile World Live (2024).
[257] T-Mobile Starlink Starts Beta Program for its Direct-to-Cell Satellite Service, GSMArena(2024).
[258] Andrew Jones, China Plans to Take 'Hack-Proof' Quantum Satellite Technology to New Heights, Space (2023).
[259] Liz Lee, et al, China Lands on Moon's Far Side in Historic Sample-Retrieval Mission, Reuters (2024).

satellites first in August,[260] and again, in October[261] in an effort to form its own Starlink rival network. These are the first steps China took in an ambitious plan to launch as many as 40,000 LEO satellites in the next decade.[262]



Source: Smallsats by the Numbers 2024, Bryce Tech at 18 (2024).

Wildcards

- **Will Increasing Space Debris Trigger a Catastrophic Kessler Effect?** As the LEO networks market continues to grow and space launches become more widespread, there is a growing issue with debris floating in low earth orbit. Approximately 85% of this debris resides within low-earth orbit and is traveling at high velocities.[263] This debris can cause significant damage to existing satellites, and raises the possibility that the density of debris will render it impossible to safely deploy and operate satellites. This prospect,

[260] Arjun Kharpal, China Launches Its Rival to Elon Musk's Starlink Internet Satellites, CNBC (2024).
[261] Andrew Jones, China Launches Second Batch of 18 Satellites for Thousand Sails Megaconstellation, Space News (2024).
[262] Steven Feldstein, Why Catching Up to Starlink Is a Priority for Beijing, Carnegie Endowment for International Peace (2024).
[263] Aneli Bongers & José L. Torres, Low-Earth Orbit Faces a Spiraling Debris Threat, Scientific American (2024).

known as the Kessler effect, can lead to a high number of collisions where the possibility of each collision exponentially increases after each collision.[264]

- **Can Low Earth Orbit Support the Surge in Satellite Deployments?** The issue of space debris rose again recently in August with the PRC launch of its Long March rocket, which created upwards of 700 debris fragments.[265] As the global race to deploy large-scale satellite constellations intensifies and other companies and nations are rapidly developing their own satellite networks — they are pushing the boundaries of low Earth orbit (LEO) capacity. SpaceX has plans to launch a mega-constellation of LEO communications satellites with approximately 42,000 satellites.[266] However, experts say that low earth orbit can only hold 72,000 satellites under the current circumstances before reaching a critical threshold that could trigger the Kessler effect to take place.[267]

What to Watch

- **China Accelerates Its Push for Global 6G Leadership Through Patents and Standards.** Looking at the broader advanced networks sector, the 6G landscape is continuing to take shape,[268] with many industry experts anticipating the emergence of 6G networks by 2028[269] and fuller scaling and deployment of 6G networks within the 2030s; however, similar to China's deployment of 5G — China is attempting to stake its claim as the leader of the 6G market. Currently, China has 6,001 6G patents, compared to the United States's 3,909.[270] While this technology is still in its early days, the global effort to standardize technological requirements is already underway.[271] Throughout this process, countries will seek to gain early-mover advantages from setting international standards closely aligned with their industry leaders' current capabilities. On both the technological and standard-setting fronts, the United States will need to ramp up attention for 6G soon, otherwise, it risks losing out to China like it did with 5G.

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[264] Kaiser Y Kuo, Space Debris: How Can the U.S. and China Avoid the Tragedy of the Commons, Sinica (2024).
[265] Andrew Jones, Chinese Rocket Stage Breaks Up into Cloud of More Than 700 Pieces of Space Debris, Space News (2024).
[266] Tereza Pultarova & Elizabeth Howell, Starlink Satellites: Facts, Tracking and Impact on Astronomy, Space News (2024).
[267] Anelí Bongers & José L. Torres, Orbital Debris and the Market for Satellites, Science Direct (2023).
[268] Isaac Myauo, Non-Terrestrial Networks: What They Are and How They Drive Innovation Towards 6G, IQT (2024).
[269] Yu Han-Chang, 6G: Key Hardware Technologies and Future Development Roadmap, IDTechEx (2024).
[270] India Makes Strides in 6G, Reaches Top Six for Global Patent Filing, Communications Today (2024).
[271] Daniel Chen Larsson, et al., 6G Standardization – An Overview of Timeline and High-Level Technology Principles, Ericsson (2024).

Quantum, 2025 Analysis

Assessment: **U.S.-Lead**	Confidence Interval: **Moderate**
Direction: **Trend Contested**	Confidence Interval: **Moderate**

The United States Leads in Quantum Innovation but China's Investment Is Substantial

Current quantum computing technology remains nascent, with a projected 5-10 years before commercialization. As a result, much of the ecosystem is focused on research and development towards the creation of a commercially-viable, fault-tolerant quantum computing system. Currently, the top two countries in quantum computing are the United States and China. The United States maintains advantages in first-mover and private sector innovation and international collaboration; however, China's massive government investment and policy strategy suggest an intensifying race for quantum advantage.

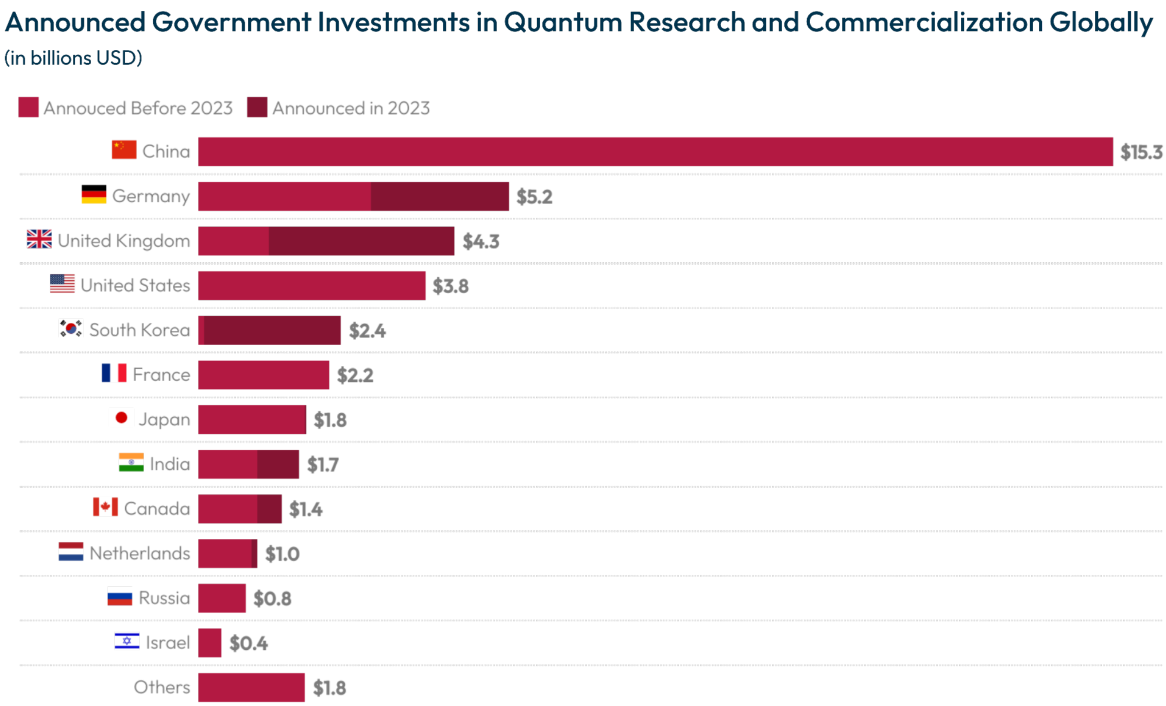
The United States holds a commanding lead in demonstrating practical quantum advantages and building a robust innovation ecosystem. In addition to showcasing quantum advantages for scientific progress in drug discovery, U.S. companies are making progress towards fault tolerant computing with Microsoft's recent development of 12 entangled logical qubits marking a significant step in error correction of quantum computers.[272] The United States continues to dominate in many of the top quantum computing modalities, building on foundational algorithms like Shor's Algorithm developed by American researchers.

However, China has made notable strides, particularly on building upon existing quantum theoretical breakthroughs and patent application filings. While U.S. researchers demonstrated time crystals within a quantum system in 2021[273] — an achievement that may help to create a room-temperature quantum computer — a PRC research team successfully actualized room temperature time crystals in 2024.[274] China also now leads in production of quantum computing papers, accounting for 22.8% of global papers compared to the United States' 21.3%; however,

[272] Cierra Choucair, Pasqal and Qubit Pharmaceuticals Use Neutral Atom QPUs to Predict Water Molecule Behavior in Drug Discovery, Quantum Insider (2024) and Matt Swayne, Microsoft-led Team Achieves Record for Reliable Logical Qubits in Quantum Computing, Quantum Insider (2024).
[273] Taylor Kubota, Stanford Physicists Help Create Time Crystals with Quantum Computers, Stanford Report (2021).
[274] Matt Swayne, It's About Time Crystals: Research Team Uses Time Crystals as Quantum Computer Controls, Quantum Insider (2024).

further analysis reveals that the U.S. publishes significantly more high-impact, meaningful quantum computing research.[275]

China has largely focused on quantum communications, but has since established quantum computing as a strategic priority since 2021, outlining it in the 14th Five-Year Plan.[276] Meanwhile in the United States, Congress passed the National Quantum Initiative Act in 2018 which for the first time created a coordinated, federal-level effort to advance quantum information science and technology. .[277]



Source: Hodan Omaar & Martin Makaryan, How Innovative Is China in Quantum?, Information Technology & Innovation Foundation (2024).

The United States leads decisively in private sector engagement, with approximately 300 quantum startups compared to China's 30, and 320 quantum investors versus China's 50.[278] This vibrant private ecosystem also complements research efforts from U.S. public research institutions. China's quantum development remains heavily centralized around state institutions, like the University of Science and Technology of China (USTC), though it has produced notable achievements through private companies like Origin Quantum. They've produced the Wukong

[275] Hodan Omaar & Martin Makaryan, How Innovative Is China in Quantum?, Information Technology & Innovation Foundation (2024).
[276] Rogier Creemers, et al.,Translation: 14th Five-Year Plan for National Informatization, DigiChina (2022).
[277] National Quantum Initiative (last accessed 2024).
[278] Alex Challans, CEO of Quantum Insider, speaking at the World Quantum Congress (2024).

system, but this system falls short of systems produced by top U.S. companies, like IBM's 1000-qubit Condor supercomputer.[279]

Government funding shows China's strategic prioritization of quantum technology, with projected investments of $15 billion compared to the U.S.'s $4 billion.[280] However, when including private sector investment of the two countries, the gap narrows significantly. The United States has secured approximately $3.7 billion in private quantum funding versus China's $255 million.[281]

Wildcards

- **Will U.S. Quantum Export Controls Impact Small Companies and Research Partnerships?** The recently proposed $2.7 billion renewal of the National Quantum Initiative Reauthorization Act signals sustained U.S. commitment to maintaining its quantum edge.[282] Additionally, recent U.S. export controls passed in September require licenses for the export of key quantum equipment, materials, and software, with additional disclosure requirements for foreign nationals working on these technologies in the United States.[283] Despite these controls aiming to prevent adversaries from gaining access to top quantum technology, these controls may potentially burden smaller U.S. quantum companies with compliance costs and complicate international research collaborations.

What to Watch

- **Quantum Software and Algorithm Development.** Hardware constraints continue to impede quantum computing's commercialization, prompting researchers to intensify software and algorithm development while awaiting hardware improvements. The United States has been a pioneer in quantum algorithm research, notably developing Shor's and Grover's algorithms, with private sector entities driving innovation — such as companies like Phasecraft and IBM's Qiskit software platform.[284] Emerging developments in quantum algorithms include advances to quantum optimization algorithms and quantum machine learning approaches.

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[279] Is Quantum Computing Underfunded in the U.S.?, IPO Club (2024).
[280] Alex Challans, CEO of Quantum Insider, speaking at the World Quantum Congress (2024).
[281] Alex Challans, CEO of Quantum Insider, speaking at the World Quantum Congress (2024).
[282] Cantwell, Young, Durbin, Daines Introduce National Quantum Initiative Reauthorization Act, U.S. Senate Committee on Commerce, Science and Transportation (2024); Science Committee Leaders Introduce Bill to Advance and Secure Quantum Leadership, Committee On Science Space and Technology (2023).
[283] Clare Zhang, US Puts Export Controls on Quantum Computers, American Physical Society (2024).
[284] Matt Swayne, Phasecraft Wins £1.2 million UK Government Contract to Develop Quantum Algorithms to Optimise Energy Grids, Quantum Insider 2024); Qiskit, IBM (last accessed 2024).

- **United States Takes Early Lead in Logical Qubit Development While China Accelerates Investment.** The race for logical qubits represents a critical metric for quantum computing progress. While physical qubit counts continue to grow, the ability to implement error correction and achieve reliable quantum operations through logical qubits will likely determine practical quantum computing capabilities. The United States currently leads in this crucial area, highlighted by Google's December achievement in stabilizing logical qubits with their Willow chip.[285]This breakthrough, which significantly reduces error rates through advanced error correction, could set a new benchmark for quantum computing. However, China's substantial investments in the field could accelerate their progress and narrow the quantum computing gap.

Semiconductors, 2025 Analysis

Assessment: **U.S.-Lead**	Confidence Interval: **High**
Direction: **U.S.-Lead**	Confidence Interval: **Moderate**

U.S. Remains in the Lead as China Looks for Workarounds.[286]

U.S. export controls on advanced chips and semiconductor manufacturing equipment demonstrate that this sector continues to be a strong point for the United States,[287] though enforcement issues have limited the effectiveness of the restrictions.[288] Collecting accurate open source information on China's chip industry has also become more challenging since the controls were instituted in 2022, with information on technical progress now treated as state secrets. Still, it is clear that Beijing is investing massive resources in "designing out" U.S. technology and developing fully indigenous GPUs, semiconductor manufacturing equipment, chip design software, and more.[289] The key bottleneck to further progress remains Extreme Ultraviolet Lithography (EUV) tools, which China cannot currently access.

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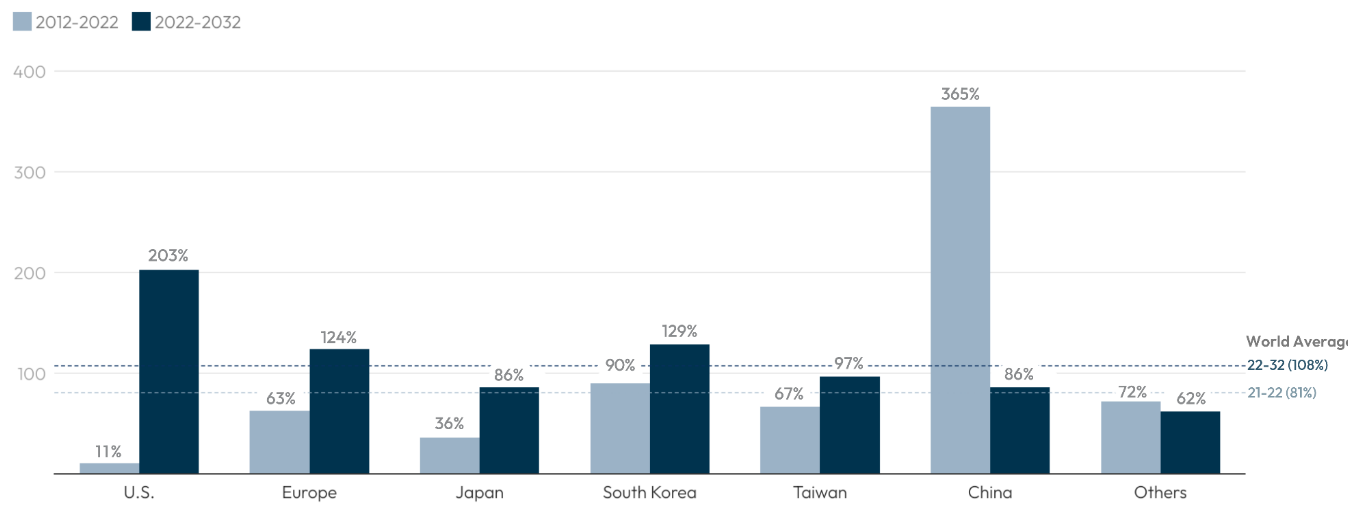
[285] Hartmut Neven, Meet Willow, Our State-of-the-Art Quantum Chip, Google Quantum AI (2024).
[286] Stephen Ezell, How Innovative Is China in Semiconductors?, Information Technology & Innovation Foundation (2024).
[287] Gregory C. Allen, The True Impact of Allied Export Controls on the U.S. and Chinese Semiconductor Manufacturing Equipment Industries, Center for Strategic and International Studies (2024).
[288] Samuel Hammond & Erich Grunewald, Spreadsheets vs. Smugglers: Modernizing the BIS for an Era of Tech Rivalry, Institute for AI Policy and Strategy (2024).
[289] Paul Triolo, The Evolution of China's Semiconductor Industry under U.S. Export Controls, American Affairs (2024).

In terms of resilience of domestic supply, the United States has made progress over the past two years. Thanks to $400 billion in private investment catalyzed by the CHIPS Act, the nation is projected to account for 28% of global leading-edge logic chip production in 2032, up from 0% in 2022.[290] Yet, U.S. vulnerabilities remain. First, Taiwan's unique concentration of expertise and economies of scale means both China and the United States remain reliant on AI chips produced in Taiwan. And second, the PRC has prioritized a massive capacity buildout for legacy semiconductors and is projected to account for 39% of global production by 2027.[291] Such an increase would overwhelm U.S. suppliers and create dependencies in strategic sectors.

Global Semiconductor Capacity Increase by Location

% Change in Wafer Starts Per Month (WSPM) Capacity



Source: 2024 State of the U.S. Semiconductor Industry, Semiconductor Industry Association at 10 (2024).

Wildcards

- **Will China Succeed in Reverse-Engineering EUV Lithography Tools?** EUV is widely regarded as one of the most complicated technologies humans have ever invented. Initial restrictions on the export of ASML's advanced lithography tools to China during the first Trump administration is widely credited with slowing Beijing's efforts to catch up in semiconductor technology. Copying these tools would require a herculean effort, but the PRC has mobilized the full resources of the party-state, pouring billions of dollars into

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[290] Emerging Resilience In The Semiconductor Supply Chain, Semiconductor Industry Association (2024).
[291] Rumors Regarding Price Reductions in Mature Process for Foundries Emerge, Signaling a Further Decrease in Prices in Q2, Trend Force (2024).

reverse-engineering efforts and assembling a state-backed EUV consortium.[292] If successful, these would drastically change the competitive balance in this sector.

- **Whither the CHIPS Act?** The incoming administration has indicated skepticism of the CHIPS Act, though initial outreach and investment commitments from TSMC began during the first Trump Administration. Passed on a bipartisan basis, CHIPS has successfully spurred over $400 billion in private investment.[293] Moves to claw back funding or slash R&D could freeze U.S. efforts to build resilience and scale novel paradigms, allowing the PRC to make up ground.

- **Who Wins the Race to Scale Novel Devices, Materials, and Architectures?** Traditional semiconductor manufacturing is pushing up against the laws of physics, pushing capital costs and energy demand for compute to unsustainable levels. A variety of post-Moore's Law chip technologies are emerging that could unlock significant gains in performance and power consumption. Technology vectors range from improvements in 3D packaging and heterogeneous integration to novel materials and devices such as spintronics, superconductor electronics, and tunnel field-effect transistors (TFETs). Candidates even include entirely new forms of computation, such as reversible computing and thermodynamic computing. Moving physics breakthroughs from the lab to the fab currently takes about 10 years, but if either the United States or China could manage to this timeline, it would change the dynamics of the competition.

What to Watch

- **China's Progress in Indigenizing the AI Hardware and Software Stack.** Weaning China off of dependence on U.S.-headquartered Nvidia for AI chips is a top policy priority for Beijing. Huawei has been tasked to develop an alternative hardware and software stack, though startups like Biren, Moore Threads, and HiSilicon, have also emerged as serious players. China's degree of success in developing competitive solutions will impact its ability to keep up in large-scale AI systems.

- **U.S. Policy Actions on Legacy Chips.** China is currently building out more capacity for legacy chips than the rest of the world combined, presenting a major national security and economic challenge for the United States.[294] The Biden Administration raised tariffs on

[292] Paul Triolo, A New Era for the Chinese Semiconductor Industry: Beijing Responds to Export Controls, American Affairs (2024).
[293] The CHIPS Act Has Already Sparked $450 Billion in Private Investments for U.S. Semiconductor Production, Semiconductor Industry Association (2024).
[294] Megha Mandavia, How China Could Swamp India's Chip Ambitions, The Wall Street Journal (2024).

legacy chips from 25% to 50%,[295] but this move left two gaps: chips manufactured outside China by PRC firms, and chips imported as components of other goods. If the new administration addresses these issues early — potentially through component-level tariffs — this would serve as an indicator that the United States will continue to tighten the screws on China's chip industry.

- **China's Progress in Advanced Packaging.** The PRC has targeted advanced packaging as a growth vector and intends to create a domestic chiplet ecosystem. These moves could help mitigate poor yields at SMIC, China's domestic national champion foundry. In addition, progress in emerging technologies like silicon photonics would boost PRC prospects in AI.

Synthetic Biology, 2025 Analysis

Assessment: **U.S.-Lead**	Confidence Interval: **Low**
Direction: **Trend U.S.**	Confidence Interval: **Low**

China is Chasing U.S. Leadership in Synthetic Biology

While the United States leads in innovation and market value, China is narrowing the gap through concentrated state investment and leveraging its superior biomanufacturing capabilities. As of 2023, the U.S. synthetic biology market dwarfed China's, with an estimated value of $16.35 billion[296] compared to China's $1.05 billion.[297] The U.S. market is projected to reach $148.93 billion by 2033,[298] while China's is expected to grow to $4.65 billion by 2030.[299] From 2008 through 2022, U.S. government funding for synthetic biology rose from $29 million to $161 million.[300] Since 2018, the PRC synthetic biology market has attracted 1,039 investment deals involving 456 synthetic biology-related companies, with disclosed total funding exceeding ¥92 billion ($12.7 billion).[301]

[295] FACT SHEET: President Biden Takes Action to Protect American Workers and Businesses from China's Unfair Trade Practices, The White House (2024).
[296] Synthetic Biology Market Size, Share, and Trends 2024 to 2034, Precedence Research (2024).
[297] China Synthetic Biology Market Analysis, Insights10 (2023).
[298] Synthetic Biology Market Size, Share, and Trends 2024 to 2034, Precedence Research (2024).
[299] China Synthetic Biology Market Analysis, Insights10 (2023).
[300] Synthetic/Engineering Biology: Issues for Congress, Congressional Research Service (2022).
[301] Wei Luo, et al., Synthetic Biology Industry in China: Current State and Future Prospects, (2023).

Biomanufacturing capacity is a key area of divergence. China dominates with 70% of global fermentation capacity, producing over 30 million tons of fermentation products annually,[302] while the United States holds just 34%.[303] This industrial-scale infrastructure enables China to commercialize synthetic biology innovations rapidly. In contrast, the United States faces bottlenecks in pilot-scale (~1,000L) and demonstration-scale (~20,000–75,000L) fermentation facilities, limiting startups' ability to scale technologies.[304] The global precision fermentation capacity, essential for synthetic biology growth, needs to expand 20-fold,[305] highlighting the urgency of addressing U.S. infrastructure deficiencies.

The United States remains a global leader in research and innovation. Between 2012 and 2023, it accounted for 33.6% of global synthetic biology publications, with 20,306 papers compared to China's 13,122 (21.7%).[306] This leadership is exemplified by breakthroughs in CRISPR gene editing,[307] computational biology,[308] and synthetic genome design,[309] as seen in companies like Intellia Therapeutics advancing *in vivo* gene editing treatments.[310] However, China excels in translating research into commercial applications. It leads in patents, holding 49.1% (25,099 patents) of global synthetic biology patents, compared to the U.S.'s 12.8% (6,524 patents), demonstrating strong translation of research to intellectual property protection.[311]

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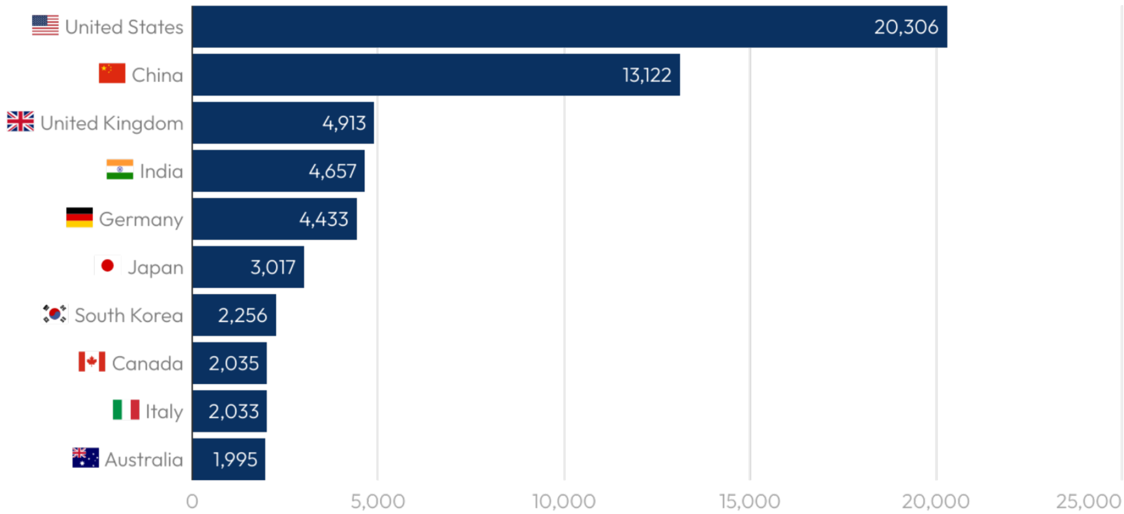
302 Wei Luo, et al., Synthetic Biology Industry in China: Current State and Future Prospects, (2023).
303 Europe Has Almost 50% of Global Protein Fermentation Capacity: Here's How to Unleash Its Potential, GFI Europe (2023).
304 Illinois Fermentation and Agriculture Biomanufacturing (iFAB) Hub: Overarching Narrative, U.S. Economic Development Administration (2023).
305 Illinois Fermentation and Agriculture Biomanufacturing (iFAB) Hub: Overarching Narrative, U.S. Economic Development Administration (2023).
306 Literature Review of the Trends and Issues in Synthetic Biology (2012–2023), UN Environment Programme (2024).
307 Natalie Healey, Next-Generation CRISPR-Based Gene-Editing Therapies Tested in Clinical Trials, Nature Medicine (2024).
308 Brianna Abbott, Nobel Prize in Chemistry Awarded to Trio Who Cracked the Code of Proteins, Wall Street Journal (2024).
309 Synthetic Genomics Advances and Promise, J. Craig Venter Institute (2022).
310 Natalie Healey, Next-Generation CRISPR-Based Gene-Editing Therapies Tested in Clinical Trials, Nature Medicine (2024).
311 Literature Review of the Trends and Issues in Synthetic Biology (2012–2023), UN Environment Programme (2024).

Countries with the Highest Publication Output in Synthetic Biology, 2012-2023



Source: Literature Review of the Trends and Issues in Synthetic Biology (2012–2023), UN Environment Programme (2024).

China has built an extensive synthetic biology ecosystem[312] through institutions like the China National GeneBank[313] and the China National Center for Bioinformation. These platforms house millions of biological samples and provide advanced tools for data archiving and visualization. Internationally, China leverages the Belt and Road Initiative (BRI) to expand its influence in synthetic biology, forming partnerships in Asia and Africa.[314] This strategy enables China to gain access to genomic data and strengthen its position in global bioeconomies. China's talent pipeline in synthetic biology is also strengthening. The country's consistent success in the International Genetically Engineered Machine (iGEM) competition underscores its ability to cultivate a new generation of bioengineers. For instance, in 2024, the ShanghaiTech University team won a gold medal in the iGEM global finals, marking the institution's eighth gold medal since its first participation in 2016.[315] This reflects China's strategic focus on nurturing domestic expertise to support long-term competitiveness in synthetic biology.

Wildcards

- **How Will Export Controls and Import Restrictions Reshape the Biotechnology Supply Chain?** The competitive landscape is increasingly shaped by policy actions as both China and the United States consider restricting the export and import of sensitive

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[312] Antonio Regalado, China's BGI Says It Can Sequence a Genome for Just $100, MIT Technology Review (2020).
[313] China National GeneBank Capable of Storing Millions of Biological Samples, Global Times (2024).
[314] Benjamin Plackett, Chinese Research Collaborations Shift to the Belt and Road, Nature (2024).
[315] ShanghaiTech Team Wins Gold Medal in the iGEM, ShanghaiTech University (2024).

biotechnologies. In December 2023, China added synthetic biology to its export control list, restricting technologies like CRISPR and gene editing for human use from export to foreign countries.[316] Previously proposed legislation like the BIOSECURE Act aimed to restrict U.S. research projects from using foreign adversaries' biotechnology, particularly from China, such as PRC-origin DNA sequencers.[317]

- **Will China Gain the Upper Hand in Emerging Biotechnology Markets?** Such restrictions potentially reshape the global distribution of biotech supply chains, as China seeks to gain strategic access to genetic resources and strengthens its position in global bioeconomies.[318] BGI, China's leading genomics organization, has engaged in global bio-prospecting through the BRI, establishing itself as a national champion in biotechnology.[319] In response, the United States has strengthened alliances with the European Union[320] and Japan[321] to enhance their collective biotechnology ecosystems. These partnerships aim to harmonize regulatory standards, promote joint research and development initiatives, and secure critical biomanufacturing infrastructure.

What to Watch

- **AI Integration Accelerates Breakthroughs in Synthetic Biology Development.** The integration of AI into synthetic biology is transforming the field. Collaborations like Ginkgo Bioworks' partnership with Google Cloud to develop generative AI platforms demonstrate AI's potential to accelerate R&D in drug discovery, agriculture, and biosecurity.[322] However, this convergence also amplifies risks. While today's AI models and AI-enabled biological design tools are largely judged to not increase the risks of malign or misuse among non-expert users,[323] experts warn that AI tools could enable unskilled actors to create biological weapons within two to three years, heightening biosecurity concerns.[324]

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- **Global Competition for Biotechnology Leadership Intensifies Through Data Access.** PRC companies have collaborated with the People's Liberation Army in genomic research, highlighting the dual-use potential of such data. In response, the United States must prioritize initiatives to gather biological data and address data governance challenges to counteract China's growing dominance in genomic data collection and utilization. Ensuring ethical standards and security measures in genomic data handling is crucial to maintaining competitiveness and safeguarding personal information.

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