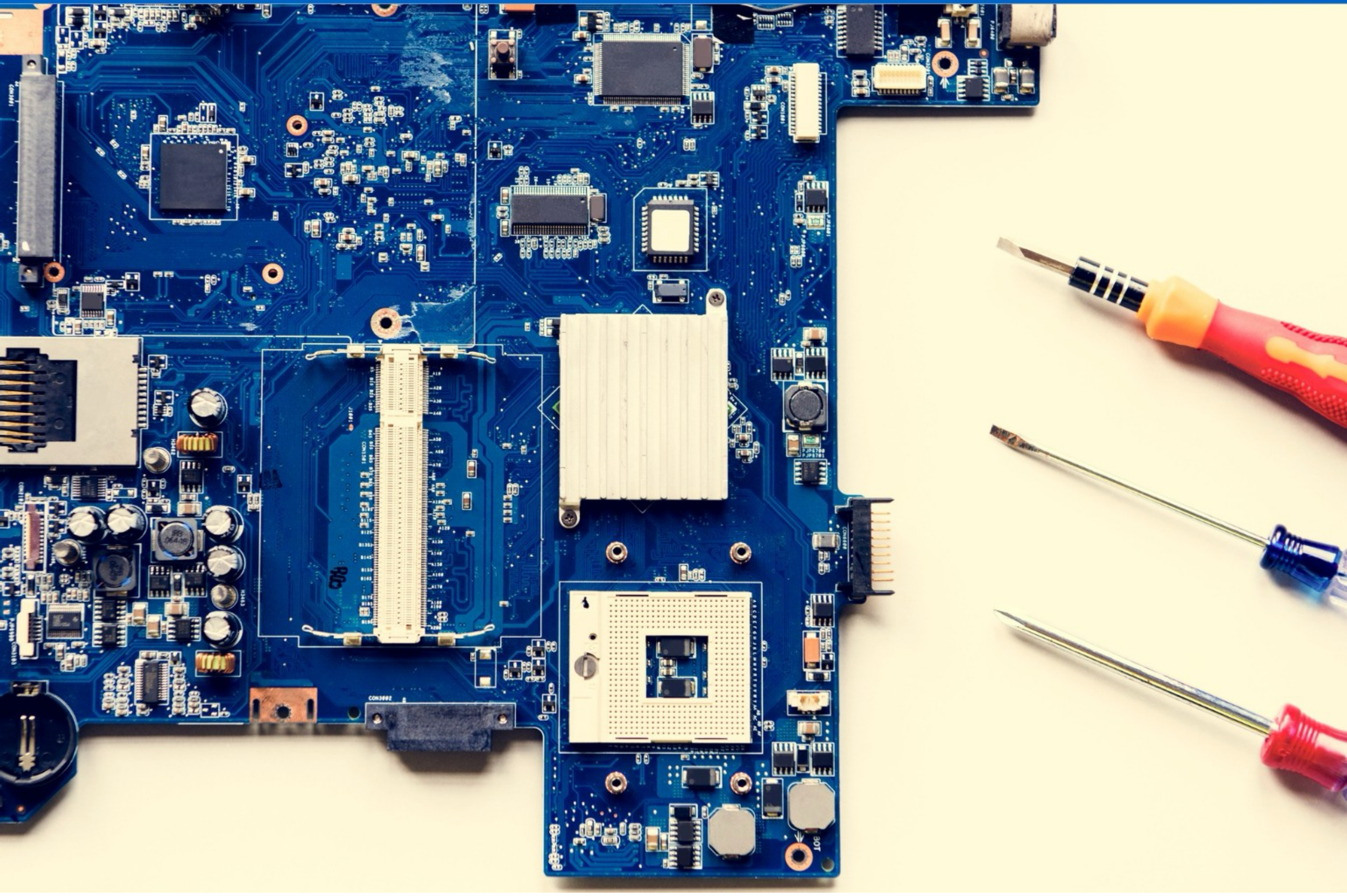
Competing for *the Frontier*

Benchmarking the US-China Technology Competition



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Executive Summary

Both Beijing and Washington treat science and technology (S&T) as integral to their competition – and, more specifically, to Beijing's efforts to leapfrog long-standing US leadership. This report seeks to assess the current competitive playing field, benchmarking US and Chinese standing in S&T.[1] The analysis finds that the United States and China define S&T similarly and prioritize parallel emerging S&T domains. However, the United States and China differ in their approaches to developing those fields and deriving national power from them: Across government, academia, and private sector, the United States places more relative emphasis on basic, or fundamental, research and development (R&D). China's resource allocations lean more toward the later stage "applied" and "experimental" domains of S&T development. Aligning with those resource allocations, Chinese strategic discourse and policy actions emphasize the competitive imperative of building high-tech infrastructures to scale and setting international technical standards. US strategic discourse is beginning to acknowledge this need as well, but only recently, with minimal action to match, and with little critical consideration of relative US strengths.

To account for the asymmetry in approach, this analysis breaks its assessment of S&T standing into three parts.

Basic R&D is treated as a "fundamental" resource for S&T capacity: This is the element on which other instruments of S&T-derived power are based. Because basic R&D does not target specific outputs, this analysis uses financial resource allocations as a metric for standing in that domain.

High-tech infrastructures are a "synthetic" building block: These systems are necessary for deploying S&T capacity and converting it into power. While it does incorporate financial allocations, the analysis of standing in this domain primarily assesses the scale and scope of infrastructure outputs, as well as government control over them. The analysis focuses on EV charging stations and satellite networks, cases selected because of their roles in Chinese and US S&T and industrial policy.

Finally, **technical standards** are treated as a critical "downstream" theater of the S&T competition: Technical standards promise high value-add, enduring positions of influence over and advantage in the global S&T ecosystem. The analysis assesses standard-setting capacity in terms of representation and leadership roles in international standards bodies. The analysis focuses on the International Standardization Organization (ISO),

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[1] This report is the first in a series of domain-focused assessments of the US-China competitive balance to be conducted by ANC. The goals of both this report and the broader effort in which it docks are 1) to unearth novel, empirical metrics of the competitive balance and 2) to leverage novel empirics to identify comparative strengths and weaknesses that can guide US national strategy for competing with China. Neither this analysis nor the broader ANC research effort are meant to be exhaustive or definitive; they reflect an initial, fact-base development and analysis that must be replicated and iterated on moving forward in order to formulate actionable, effective national strategy.

the International Telecommunications Union (ITU), and the International Electrotechnical Commission (IEC) because those are the multinational standard-setting bodies that Beijing prioritizes.

This analysis finds that:

- In basic R&D, as measured by resource allocations, US capacity far outstrips China's, both numerically and as a share of national and corporate wealth. This holds at a macro level, taking government, academia, and private sector actors together. It also holds at a more disaggregated level, looking only at the resource allocations of each side's respective powerhouse technology companies. Trendlines suggest that the gap will endure moving forward.

- Chinese discourse and policy suggest a deliberate prioritization of high-tech infrastructures that is absent from analogous US deliberations. In emerging infrastructures (e.g., electric vehicle charging stations) this prioritization manifests in a determinative advantage for China. In more legacy ones (e.g., satellites), the US appears to maintain a quantitative advantage with larger infrastructure networks. But the US networks tend to be decentralized and fragmented. China's are largely centralized, under Beijing's control. This asymmetry may propel a differentiated Chinese strategy and deliver results able to tilt the balance in China's favor despite quantitative disadvantage.

- In technical standards, Beijing deploys a deliberate competitive strategy that has only recently been recognized in the United States, and for which there is not yet a US response. However – as with China's standing in more legacy technology infrastructures – this emphasis may not yet have yielded a determinate advantage for China in international standard-setting bodies. In the International Standardization Organization (ISO) and International Electrotechnical Commission (IEC), China has marginally more "members" than does the United States. However, China appears still to lag the United States in influence, as measured by leadership over significant technical committees. By contrast, in the International Telecommunications Union (ITU), an organization with a larger share of its membership drawn from industry, China's representation and leadership well exceed that of the United States. Across all three, Chinese representatives are more tightly tied to the Chinese government and the Chinese Communist Party (CCP) than their private sector, fragmented US counterparts are to Washington – or any other centralized source of policy. As with the infrastructure case, this centralization that may tilt the influence balance over standards organizations in Beijing's favor.

Introduction

"Science and technology have become the main battlefield of the international strategic game," declared Xi Jinping at the 10th National Congress of the China Association of Science and Technology (CAST) in May 2021. He continued: "The competition around the commanding heights of science and technology is unprecedentedly fierce."[2] Five years earlier, at the 9th CAST Congress, he had called science and technology "the weapons of the country:" "One of the key reasons why Western countries have been able to dominate the world in modern times is that they have mastered high-end technology."[3]

This idea that science and technology (S&T) are integral to modern nation-state competition – and that China is rising to challenge long-standing US leadership – is echoed in the United States. "China and other countries are closing in fast [in emerging technology investments]," declared President Biden in a speech to a joint session of Congress on April 28, 2021. "We have to develop and dominate the products and technologies of the future."[4] In discussing the US Innovation and Competition Act of 2021 (USICA) – a massive investment in science and technology billed as a program to compete with China – Senate Majority Leader Chuck Schumer argued that "whoever wins the race to the technologies of the future is going to be the global economic leader with profound consequences for foreign policy and national security as well.[5]" Or, more succinctly, per a group of national technology and policy leaders co-convened by Eric Schmidt and Jared Cohen in fall 2020, "America's technological leadership is fundamental to its security, prosperity, and democratic way of life. But the vital advantage is now at risk, with China surging to overtake the United States in critical areas."[6]

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[2] "要点：中国要在高龄等关键技术上全力攻坚瞄准重点信息等前沿领域 [Key Points: China Should Make All-Out Efforts in Key Technologies Such as Advanced Age to Target Frontier Fields Such as Key Information]," *Reuters*, May 28, 2021.

[3] "习近平：科技是国之利器 [Xi Jinping: Technology Is a Weapon of the Country]," *China Cadre Learning Network*, June 5, 2016.

[4] "Remarks by President Biden in Address to a Joint Session of Congress," April 28, 2021. https://www.whitehouse.gov/briefing-room/speeches-remarks/2021/04/29/remarks-by-president-biden-in-address-to-a-joint-session-of-congress/

[5] "The Senate Passes a Bill to Encourage Tech Competition, Especially with China," *The Associated Press*, June 8, 2021. https://www.npr.org/2021/06/08/1004600001/the-senate-passes-a-bill-to-encourage-tech-competition-especially-with-china

[6] China Strategy Group, "Asymmetric Competition: A Strategy for China and Technology," Fall 2020. https://www.documentcloud.org/documents/20463382-final-memo-china-strategy-group-axios-1

Parallel Priorities

The two sides are equally consistent in their framings of S&T. Both the US and Chinese governments break S&T research and development (R&D) into three stages: Basic, applied, and experimental. And both rely on the same language – almost exactly -- to define those stages (see table 1).

Table 1: Definitions of Basic, Applied, Experimental Research[7]

	China: National Bureau of Statistics	US: National Science Foundation
Basic	Theoretical or experimental research conducted to obtain new knowledge about basic principles of phenomena and observable facts; it does not have any specific application or purpose.	Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
Applied	Creative research carried out to acquire new knowledge, mainly for a specific purpose or goal.	Original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.
Experimental	The use of existing knowledge obtained from basic research, applied research, and practical experience to produce new products, materials and devices; establish new processes, systems, and services; and to control, improve, or systematize the above-mentioned operations that have been produced and established.	Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

Moreover, in the competition for emerging S&T prowess, the United States and the People's Republic of China (PRC) appear to emphasize parallel fields. Both governments released high-level documents in Spring 2021 outlining priority areas for S&T and plans for pursuing them. The identified priority domains were near-identical. The 14th Five-Year Plan for National Economic and Social Development of the PRC and the Outline of Long-Term Goals for 2035 (hereafter 14th FYP) issued by the Chinese Communist Party in March 2021 listed a set of "strategic emerging industries" as well as "frontier fields of technology and industrial transformation" that together constitute target areas for China's national S&T system (see table 2). These areas are consistent with Beijing's long-standing S&T priorities, as reflected in the State Council's 2006 National Medium and Long-Term Program for Science and Technology Development（2006-2020）(MLP),[8] 2010 Strategic Emerging Industries Initiative,[9] and 2015 Made in China 2025 plan,[10] as well as China's 13th and 14th Five Year Plans.[11] Also in March 2021, the US Congress passed the United States Innovation and Competition

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[7] "主要统计指标解释 [Explanation of Main Statistical Indicators]," National Bureau of Statistics of China, Accessed August 9, 2021; "Definitions of Research and Development: An Annotated Compilation of Official Sources," National Science Foundation, March 2018. https://www.nsf.gov/statistics/randdef/rd-definitions.pdf

[8] State Council, "国家中长期科学和技术发展规划纲要（2006-2020）[National Medium and Long-term Science and Technology Development Plan Outline (2006-2020)," December 20, 2005.

[9] For English language discussion, see: "China's Strategic Emerging Industries: Policy, Implementation, Challenges, & Recommendations," US China Business Council, March 2013.

[10] State Council of the People's Republic of China, "中国制造2025 [Made in China 2025]," May 2015.

[11] See Katherine Koleski, "The 13th Five-Year Plan," US-China Economic and Security Review Commission, February 13, 2017.

Act (USICA), billed in large part as a response to China's challenge in S&T. That law included ten "key technology focus areas."[12] Those areas mirror Beijing's priority domains (see table 2).

Table 2: Target Fields of Emerging Science and Technology, as Reflected in Official Policy[13]

Strategic Emerging Industries (14th FYP)	Frontier Fields of Technology and Industrial Transformation (14th FYP)	Key Technology Focus Areas (USICA)
	Next-generation artificial intelligence	Artificial intelligence, machine learning, autonomy, and related advances
High-end equipment (e.g., intelligentization)	Integrated circuits	High performance computing, semiconductors, and advanced computer hardware and software
	Quantum information	Quantum information science and technology
	Brain science and brain-like research	Robotics, automation, and advanced manufacturing
Aerospace and marine equipment (e.g., aero engines, satellite infrastructure, satellite applications, smart ships)	Deep space, deep sea, and polar exploration	Natural and anthropogenic disaster prevention or mitigation
	Future networks	Advanced communications technology and immersive technology
Biotechnology (e.g., biomedicine, bio-agriculture, bio-manufacturing)	Genetic and biotechnology research; medicine and health	Biotechnology, medical technology, genomics, and synthetic biology
Next generation information technology (e.g., industrial Internet, big data, advanced communications)		Data storage, data management, distributed ledger technologies, and cybersecurity, including biometrics
New energy; new energy vehicles; environmental protection technology (e.g., nuclear, solar, wind, hydrogen, biomass energy)	Hydrogen energy and energy storage	Advanced energy and industrial efficiency technologies, such as batteries and advanced nuclear technologies
New materials (e.g., high-performance composite materials, new functional rare earth materials, information function materials)		Advanced materials science, including composites and 2D materials

Different Competitive Approaches

However, while the US and China appear to prioritize a similar set of emerging S&T fields, both resource allocations and strategic discourse suggest that the two players diverge on how to develop those fields and competitive advantage within them. The United States tends, and has historically tended, to assign more weight to early stage, or basic, research and development than does China, while China concentrates a greater relative share of resources on applied and, especially, experimental science and technology. According to

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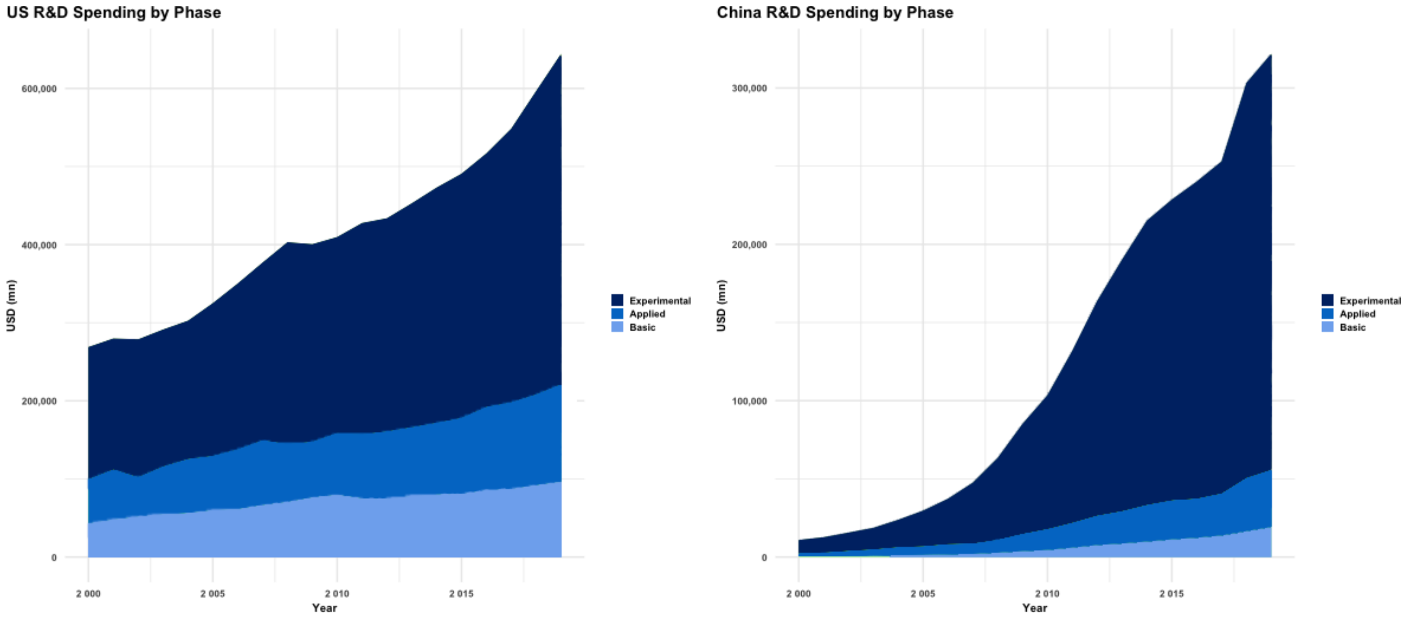
[12] "S.1260: United States Innovation and Competition Act of 2021," accessed August 1, 2021. https://www.congress.gov/bill/117th-congress/senate-bill/1260/text.

[13] "发展战略性新兴产业 [Develop Strategic Emerging Industries]," *China Economic Net*, December 10, 2020; "中华人民共和国国民经济和社会发展第十四个五年规划和2035年远景目标纲要 [The Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Long-Term Goals for 2035]," March 13, 2021; "United States Innovation and Competition Act of 2021," Congress.gov, https://www.congress.gov/bill/117th-congress/senate-bill/1260/text.

National Science Foundation (NSF) statistics, between 2000 and 2019, the average share of national R&D expenditures dedicated to basic research in the US – across the government, private sector, and academia – was 17.2 percent, with applied research receiving 20.2 percent and experimental 62.3 percent.[14] By contrast, China's averages, as reported by China's National Bureau of Statistics, were 5.2, 14.1, and 80.7, respectively.[15] For both countries, this average is a representative statistic, across the entire time span: The relative shares have remained largely consistent from year to year (see figure 1).

Figure 1: R&D Expenditures by Phase, US and China (2000-2019)



Chinese academic discourse contextualizes this focus on later stage R&D, arguing that in today's scientific and technological revolution, competitive advantage requires not only innovating at a fundamental level, but also applying technologies, doing so to scale, and developing accompanying new infrastructures and standards.[16] Lei Shaohua of Peking University offered a clear example of this framing in a 2019 article in *World Economy and Politics,* a journal under the Chinese Academy of Sciences. "Different from traditional industries," he wrote, "emerging industries are characterized by a 'high-tech threshold, high standardization, high market capacity, and high-cost supporting infrastructure." As a result, while "the competition among major powers in the world today" is one of science and technology, the contest extends beyond innovation also to include "rapid application of the industrial chain….In the era of globalization, the most important factors in competition are industrial policy, cutting edge technology, and market scale."[17] Lei further stressed that "only applied

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[14] "National Patterns of R&D Resources: 2018-2019 Update," National Science Foundation, April 9, 2021. https://ncses.nsf.gov/pubs/nsf21325#data-tables

[15] 全国高科技经费收入统计公报 [Statistical Communiqué on National High-Tech Funds Allocations], National Bureau of Statistics of China, Accessed August 9, 2021.

[16] Emily de La Bruyere and Nathan Picarsic, "Military-Civil Fusion: China's Approach to R&D, Implications for Peacetime Competition, and Crafting a US Strategy," Naval Postgraduate School Defense Acquisition Symposium, May 2019.

[17] Lei Shaohua, "超越地缘政治: 产业政策与大国竞争["Beyond Geopolitics: Industrial Policy and Great Power Competition]." *World Economy and Politics*, 2019 (5). Or, elsewhere, "the R&D application and market scale of core technologies under the guidance of industrial policies determine the country's wealth accumulation and further R&D investment. Industrial policies have become the core of competition among major powers. (Ibid.)

technology is technology. Otherwise, it is simply research. Market application determines the direction of technology development."[18]

Lei emphasized that his point applied across the entire industry chain just as it does across all phases of S&T development: "Whoever controls the entire industrial chain from low-end to high-end controls the global industrial structure." He also suggested that China might have an advantage over the US in this new type of S&T competition:

> Emerging industries are increasingly dependent on new infrastructure. But in a free-market competition system…the new industries themselves cannot afford the costs…The US cannot directly invest in the construction of new infrastructure. Therefore, it is gradually losing its competitive advantage in the new round of global construction.[19]

By contrast, China as an emerging country "has the advantage of…new infrastructure" as well as manufacturing capacity, and as a non-free market system has the advantage of "national mobilization:" "The competition among major powers in the era of globalization has turned to a contest between industrial policies."[20]

Lei is by no means alone in this framing. Zhao Longyue, Director of the China Society of Economic Law[21] presented a similar – if perhaps more extreme – version of the same argument in a 2016 article in *International Trade:* "The strategic game among big powers is no longer limited to market scale competition and technological superiority competition. It is more about system design competition and rule-making competition."[22] Both arguments, and the larger strains of Chinese discourse that they represent, informed the decision in this analysis to emphasize relative capacity in high-tech infrastructures and influence over the global standard-setting system.

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[18] Lei stresses that his point applies all across the industry chain just as it does across all phases of S&T development: "Whoever controls the entire industrial chain from low-end to high-end controls the global industrial structure." He also suggests that China may have an advantage over the US in this new type of S&T competition. "Emerging industries are increasingly dependent on new infrastructure. But in a free -market competition system…the new industries themselves cannot afford the costs." "The US cannot directly invest in the construction of new infrastructure. Therefore, it is gradually losing its competitive advantage in the new round of global construction." By contrast, China as an emerging country "has the advantage of…new infrastructure" as well as manufacturing capacity, and as a non-free market system has the advantage of "national mobilization:" "Emerging powers have devoted their national power to accumulating late-comer advantages in technology R&D and application [emphasis added], and have begun gradually to challenge the traditional powers." Or, elsewhere, "Although the dominant powers still maintain an absolute technological advantage, in the long run…as emerging powers rise in the industrial chain and see their technology advance, the gap in technology and market competitiveness will shrink. Industrial policies, core technologies, and market size jointly determine the competitive position of major countries in the global industrial chain. The competition among major powers in the era of globalization has turned to a contest between industrial policies." (Lei Shaohua, "超越地缘政治: 产业政策与大国竞争["Beyond Geopolitics: Industrial Policy and Great Power Competition]." *World Economy and Politics*, 2019 (5).)

[19] Ibid.

[20] He also wrote that: "Emerging powers have devoted their national power to accumulating late-comer advantages in technology R&D and application [emphasis added], and have begun gradually to challenge the traditional powers." Or, elsewhere, "Although the dominant powers still maintain an absolute technological advantage, in the long run…as emerging powers rise in the industrial chain and see their technology advance, the gap in technology and market competitiveness will shrink. Industrial policies, core technologies, and market size jointly determine the competitive position of major countries in the global industrial chain. (Ibid.)

[21] A national academic organization subordinate to the PRC's Ministry of Justice.

[22] Zhao Longyoue and Li Jiasheng, "WTO与中国参与全球经济治理 [The WTO and China's Participation in Global Economic Governance," *International Trade*, 2016.

Benchmarking S&T Standing

The chapter that follows seeks to benchmark relative US and Chinese standing in S&T. To account for the asymmetry in US and Chinese prioritizations of R&D stages, the role that infrastructure and system design play in the Chinese competitive logic, and the analytical imperative to assess not only capacity but also deployment of that capacity, the analysis treats early-stage S&T as only one part of the equation; as the "fundamental" building block in S&T standing. In addition, the analysis seeks to measure relative capacity in new infrastructures, as a "synthetic" building block of S&T capacity, and influence over international technical standards, as the "downstream." As Lei argues, infrastructures, including emerging networks and platforms are necessary tools for deploying emerging technologies to scale and across borders. And technical standards, constitute an emerging ruleset for the current scientific and technological revolution. This ruleset promises to influence how that revolution develops as well as the competitive hierarchy within it.

Methodology

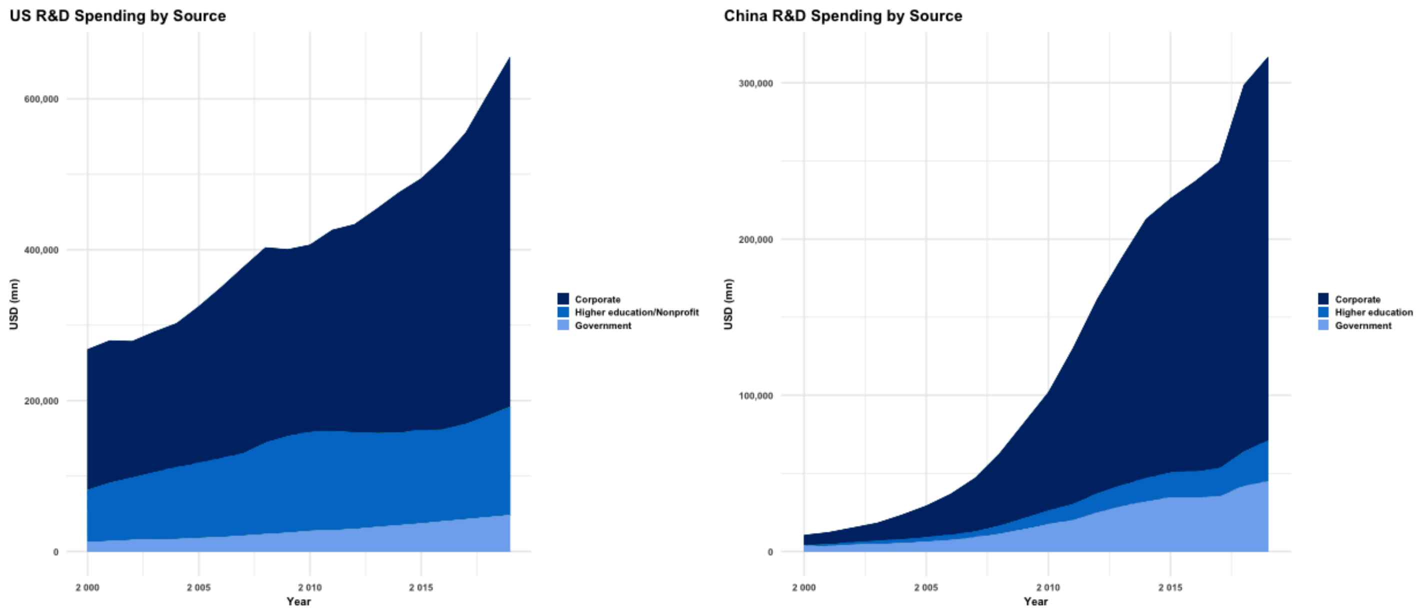
Both the US and Chinese systems define basic R&D as conducted independent from assessment of downstream applications, without a set use case, or application, in view. Because specific outputs are not the object of basic R&D, this analysis uses financial resource allocations rather than outputs as a metric for standing in that domain. Unless otherwise noted, relevant data are drawn from the US National Science Foundation and the National Bureau of Statistics of China, and refer to spending across all sectors of the two systems, including government, commercial, and academic R&D. As with all datasets, and in particular Chinese official data, these figures have their limitations. This analysis assumes that while absolute investment levels reflected may be inaccurate, these data reliably reflect relative trends over time.

In benchmarking capacity in high-tech infrastructures, the analysis focuses on systems that support priority technological domains of the US and Chinese governments (as reflected in table 2). The analysis also accounts for Beijing's emphasis on "new infrastructures," a broad category – including electric vehicle (EV) charging stations, the industrial Internet of Things, data centers, and satellites – that refers to the networks and platforms necessary to support large-scale application of emerging industries. The analysis explores two cases in particular: EV charging systems and space satellites. While it does incorporate financial allocations, the analysis focuses primarily on the scale and scope of infrastructure outputs, as well as government control over them.

Multilateral standard-setting organizations are instrumental in defining international technical standards. These organizations are composed of voting members organized into sector- or technology-specific groups. In theory, members select among standards proposals based on technological merit. However, they also risk selecting based on individual, commercial, or national interests – or in response to coercion on the part of others representing individual, commercial, or national interests. For decades, Chinese government planning has sought to increase membership and leadership positions in multilateral standard-setting organizations in order to influence the international standards ecosystem.[23] This analysis measures influence over international standards bodies based on representation and leadership posts. The analysis focuses on the International Standardization Organization (ISO), the International Telecommunications Union (ITU), and the International Electrotechnical Commission (IEC).

Throughout, the analysis focuses on private sector actors. These are the dominant players in driving technological advances today – a critical difference vis-a-vis the Cold War environment. In both the US and China, commercial S&T advances and spending far exceed those of the public sector (see figure 2). In 2019, the corporate sector accounted for 76.4 percent of China's total R&D expenditures and 70.7 percent of those of the US.

Figure 2: R&D Expenditures by Source, US and China (2000-2019)



Metrics: A Topline Picture

Based on first-order, surface-level metrics, US S&T capacity trumps China's. America's tech sector is multiple times larger than China's. The top ten US public technology companies have a combined market cap of over 11 trillion USD. That figure sits at less than 1.9 trillion for China's top ten. The largest public Chinese tech company, Tencent, would rank only seventh in the US. The market cap of China's tenth largest public tech

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[23] Emily de La Bruyere, "China's Quest to Shape the World through Standards Setting," The Hinrich Foundation, July 13, 2021. https://www.hinrichfoundation.com/research/article/tech/china-quest-to-shape-the-world-through-standards-setting/.

company, Kuaishou Technology, is about a quarter of the size of the tenth largest US public tech company, Oracle.

In addition, the US outspends China on R&D by a factor of two while boasting an R&D intensity[24] more than 0.8 percentage points higher than China's. As measured by dollars, this gap is not shrinking: It was almost exactly the same in 2019 (334 billion) as it was in 2000 (257 billion USD, or the equivalent of about 382 billion USD in 2019). However, as spending is increasing at approximately the same rate for both countries, China's *share* of US R&D expenditures has grown significantly over the past two decades (see Figure 3).

Table 3: US vs. China: Top Ten Public Technology Companies by Market Cap[25]

	United States		China	
Rank	**Company Name**	**Listed Exchange**	**Company Name**	**Listed Exchange**
1	Apple	NASDAQ	Tencent	HKSE
2	Microsoft	NASDAQ	Alibaba	HKSE, NYSE
3	Alphabet (Google)	NASDAQ	Meituan	HKSE
4	Amazon	NASDAQ	Pinduoduo	NASDAQ
5	Facebook	NASDAQ	Jingdong Mall	HKSE, NASDAQ
6	Tesla	NASDAQ	Hikvision	SHE
7	Nvidia	NASDAQ	Xiaomi	HKSE
8	Paypal	NASDAQ	NetEase	HKSE, NASDAQ
9	Adobe	NASDAQ	WuXi AppTec	SSE, HKSE
10	Oracle	NYSE	Kuaishou Technology	HKSE

Yet this topline picture risks obscuring competitive nuances. The United States and China approach their S&T ecosystems with different priorities and through different organizational models. These differences foster asymmetries that may bely the competitive balance suggested by high-level figures. Different emphases on basic as opposed to applied or experimental research offer a prime example: The US lead over China in R&D spending is greatest in the early stages of that R&D. The US spends some five times as much money as does China on basic research, compared to three times in applied research and two in experimental.

The asymmetries do not end there. They also include institutional differences, notably the relative centralization of China's S&T ecosystem. In 2019, the US and Chinese governments accounted for approximately 22 and 14 percent of total R&D spending, respectively; the commercial sector 71 and 76; and educational and nonprofit institutions 7 and 8 percent (see figure 2). Those figures are roughly equivalent. However, the categories being compared are not. The Chinese government has far more influence over its commercial, educational, and nonprofit players – including the R&D they conduct and the way their R&D results are used – than does the US government. This could create a competitive disadvantage for China:

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[24] Defined as R&D expenditures as a percent of GDP.

[25] https://companiesmarketcap.com/usa/largest-companies-in-the-usa-by-market-cap/

Centralization and government control could stymy innovation. However, it could also constitute an advantage: Centralization and government control could provide the coordination and financial backing necessary to apply R&D results to scale, as well as to harmonize across elements of the S&T ecosystem.

Figure 3: US vs. China: Total R&D and R&D Intensity, 2000-2019[26]

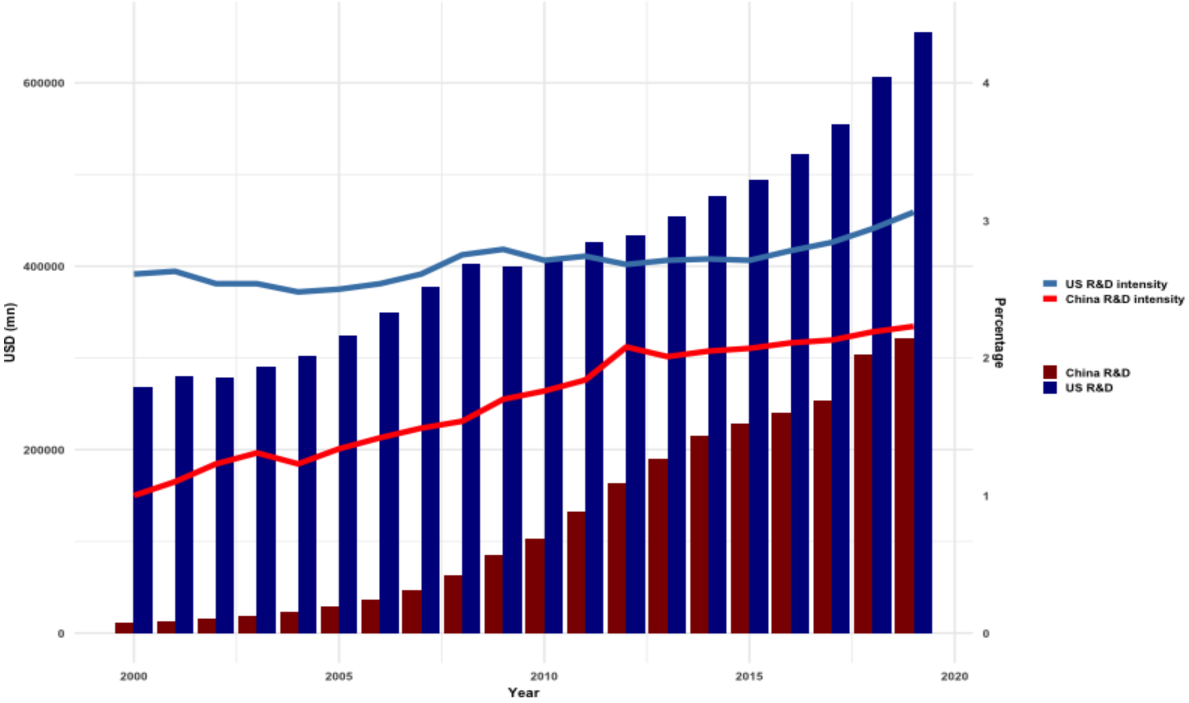
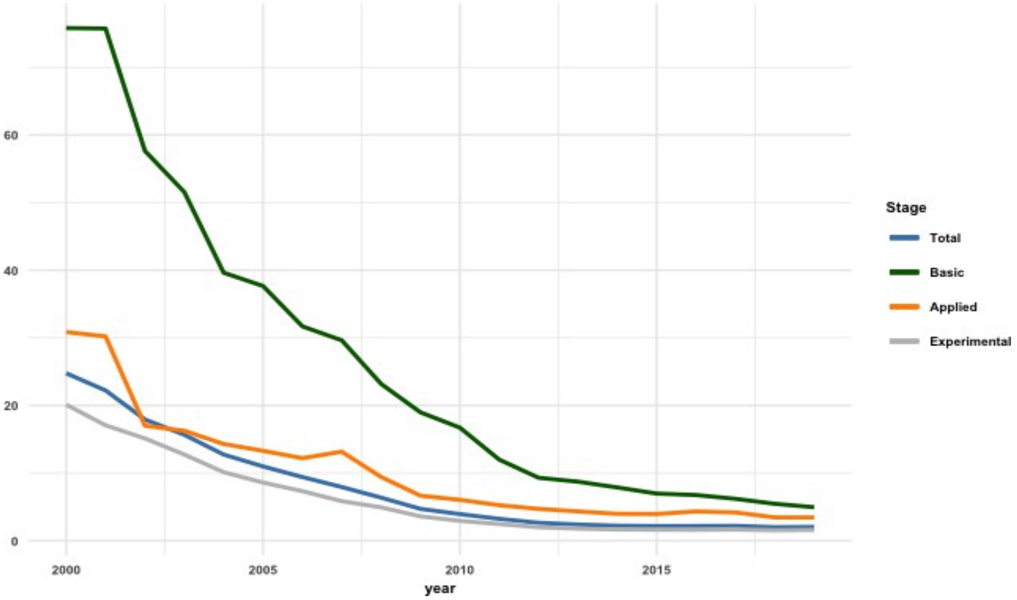


Figure 4: US R&D Spending as a Multiple of China's, by R&D phase



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[26] National Patterns of R&D Resources: 2018-2019 Update," National Science Foundation, April 9, 2021. https://ncses.nsf.gov/pubs/nsf21325#data-tables; 全国高科技经费收入统计公报 [Statistical Communiqué on National High-Tech Funds Allocations], National Bureau of Statistics of China, Accessed August 9, 2021.

Fundamental

This section seeks to benchmark relative capacity in basic R&D or, put otherwise, the fundamental resource on which scientific and technological standing is based. Both the US and Chinese official research ecosystems define basic S&T as taking place without a set use case, or outcome, in mind. Because that suggests basic R&D is conducted without a defined output objective, this analysis measures standing based on resource allocations not outcomes.[27] The analysis begins by assessing overall expenditures. It then focuses on those R&D expenditures of leading tech companies in the two countries.

Overall Basic R&D

In R&D supporting basic S&T, the US – including government, commercial sector, and educational institutions – far outspends China. These US players also prioritize basic R&D, both relative to later stages and relative to overall wealth, more than do their Chinese counterparts. US basic R&D expenditures totaled more than 96 billion USD in 2019. China's sat at less than 20 billion. Where the US devoted more than 14 percent of total S&T spending to basic R&D in 2019 – and an average of more than 17 percent between 2000 and 2019 – those figures were a mere 4.6 and 6 percent for China, respectively.

Basic R&D is also the stage in which the dollar gap between US and Chinese spending has grown the most since 2000, from 42 billion 2000 dollars (or about 62.6 billion 2019 dollars) to about 76.6 2019 dollars.[28]

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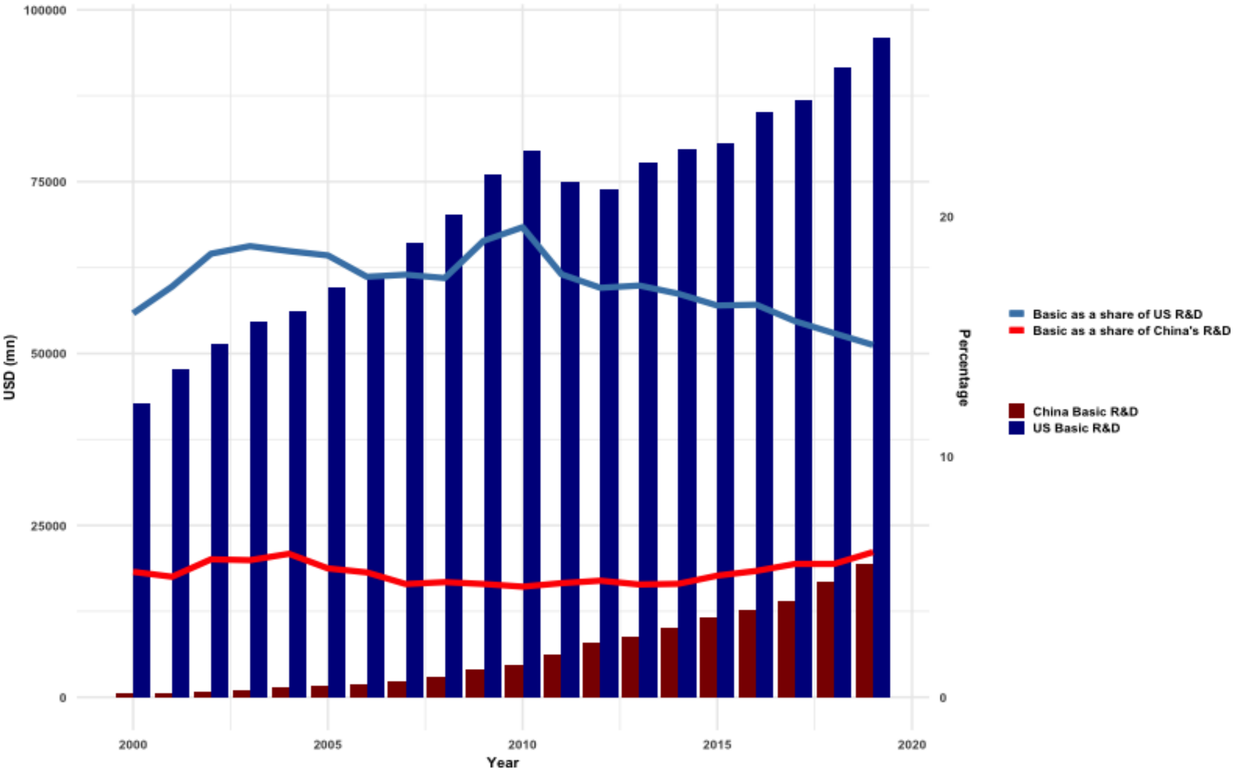
[27] This analysis explicitly does not treat people as the basic resource in S&T, though some might suggest that they should be considered as such. First, to the extent that people are critical inputs in developing S&T capacity, they are in large part a function of the resources they can access: Mark Zuckerberg might have transformed the world. But he and his network were a function of the resources of Harvard University and Facebook spends billions of dollars in research and development. Second, the flow of people across porous natural borders that defines today's global environment – and especially S&T environment – separates individuals from the national competitive context.

[28] By contrast, the gap in applied spending remained relatively constant: 82.4 billion 2019 dollars in 2000 and 88.5 billion in 2019, and that in experimental spending shrank from 239 billion 2019 dollars to 257.

Figure 5: US vs. China: Basic R&D Expenditures, Total and as a Share of All R&D, 2000-2019



Focusing on the Leaders: "Big Tech" R&D

This difference in spending and relative prioritization also applies for most of the so-called "big tech" companies driving today's technological development and application:[29] Facebook, Amazon, and Google in the US, for example, and Tencent, Alibaba, and Baidu in China. These companies are pioneering S&T advances. They are also pioneering the translation of those advances into new technological systems. If there is a single set of actors most reflective of the S&T revolution, it is these companies. And for the most part, the key US big tech companies dedicate more resources, both as a total figure and as a share of their overall operations, to research and development than do their Chinese counterparts.

Here, R&D is a broad category, and not a clear cut one. Figures are drawn from self-reporting of R&D spending in company annual reports. That reporting relies on amorphous definitions of R&D that are bound to vary from company to company. Moreover, it does not distinguish between stages of R&D (e.g., basic, applied, experimental). However, while not perfect metrics, these R&D statistics do indicate the company's perceived allocation of resources between developing fundamental capacity in S&T and applying or operating that capacity. As such, these figures provide a rough proxy, and rough basis for comparison, of basic R&D in the corporate context.

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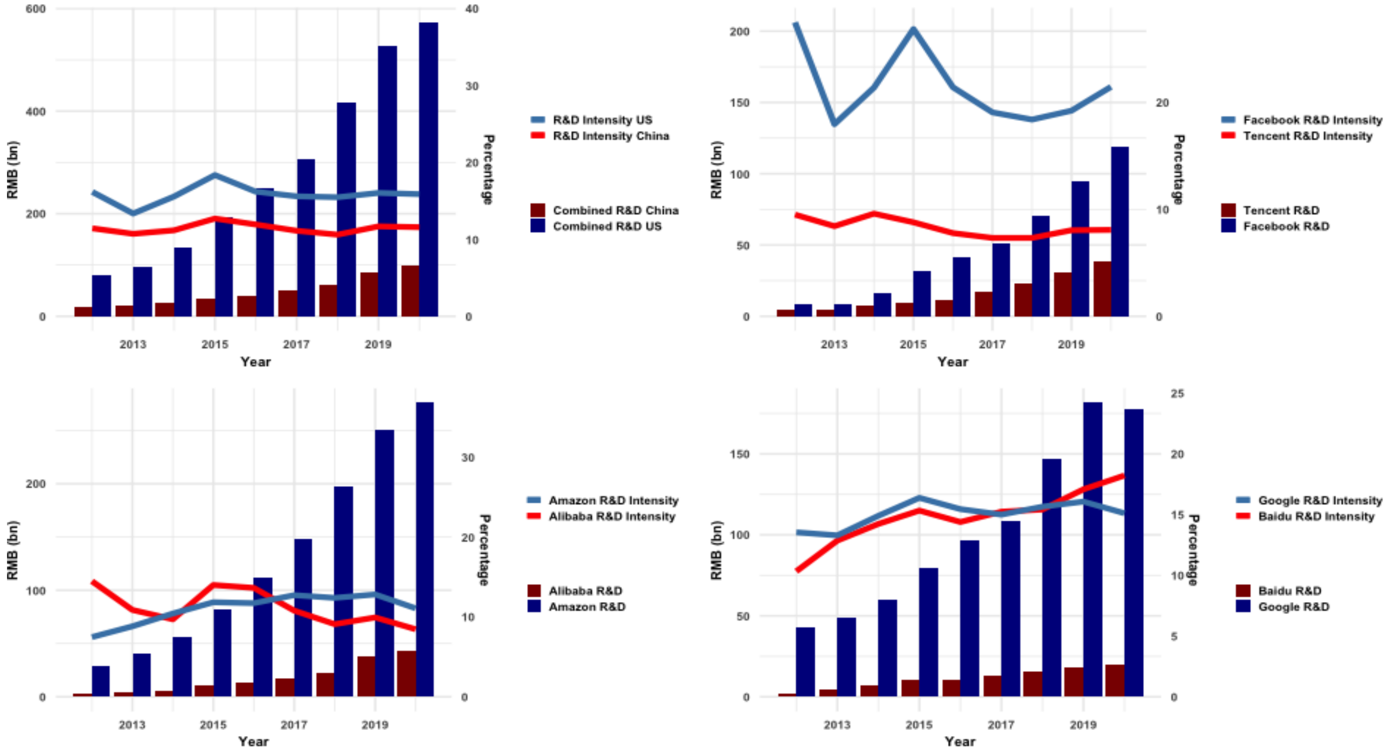
[29] See discussion on the subject in Caleb Foote and Robert Atkinson, "Federal Support for R&D Continues Its Ignominious Slide," Information Technology and Innovation Foundation, August 12, 2019. https://itif.org/publications/2019/08/12/federal-support-rd-continues-its-ignominious-slide

Figure 6: Facebook, Amazon, Google vs. Tencent, Alibaba, Baidu: R&D and R&D Intensity, 2012-2019[30]



Facebook, Amazon, and Google – and their Chinese counterparts Tencent, Alibaba, and Baidu – offer a useful starting point. The three US players are among the five biggest public tech companies in the world, by market cap. They have developed revolutionary platforms across different sectors. The three Chinese players offer direct counterparts. Tencent and Alibaba are also China's two largest public tech companies by market cap.

The combined R&D spending of Facebook, Amazon, and Google outranks that of Baidu, Alibaba, and Tencent by a factor of more than five to one: According to their annual reports, the US companies spent a combined 88 billion USD on research and development in 2020, compared to about 1.8 billion for Tencent, Alibaba, and Baidu.

Facebook, Google, and Amazon in aggregate – and Facebook and Google as individual companies -- also dedicate more *relative* resources to R&D than do their Chinese counterparts: The three US companies spent an average of 20, 12.1, and 15.5 percent of their total revenue on R&D between 2016 and 2020, respectively, compared to 7.7, 10.4, and 16 percent for Tencent, Baidu, and Alibaba. This difference appears to be enduring: Baidu is not only the one Chinese player to outspend its US counterpart in terms of R&D intensity, it is also the only of the three Chinese companies to have seen an increasing share of its revenue go to R&D over the past decade (see figure 6).

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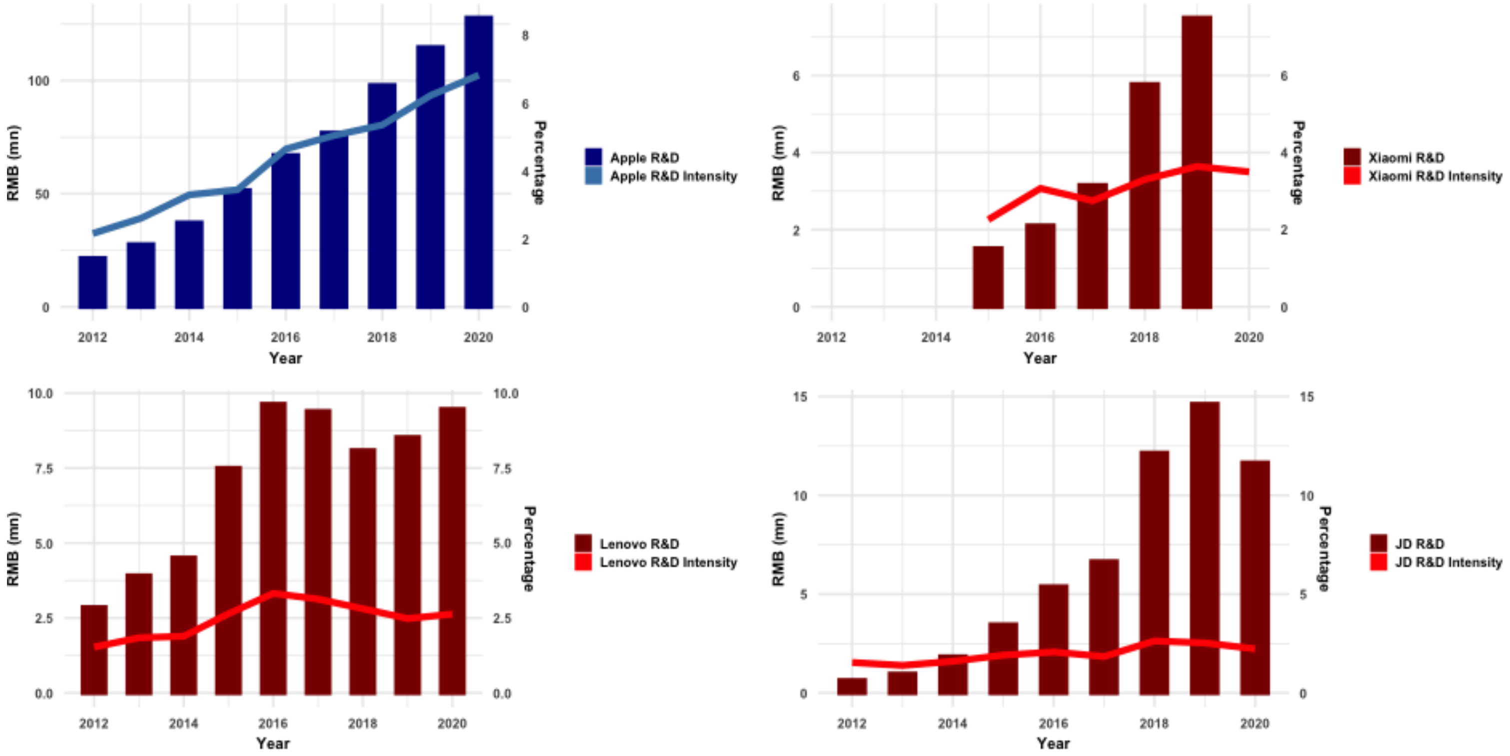
[30] Data collected from company annual reports, WIND Data; similar data also discussed in: "数据会说话：定位中国硬核科技公司 [Data Speaks: Positioning Chinese Hardcore Technology Companies]," IYIOU, February 1, 2001.

As examples, Baidu, Alibaba, and Tencent may overstate the Chinese tech sector's R&D intensity. The three companies, and especially Baidu, appear to prioritize R&D *more* than do other, relatively mature (e.g., non-start-up) leading Chinese tech companies. JD, a leading Chinese e-commerce company and Alibaba's primary domestic competitor, had an R&D intensity of just 2.23 percent in 2020. Its R&D expenses as a share of total revenue have averaged 1.89 percent over the past ten years – and have at no point exceeded 2.63 percent. In the more hardware-focused space, Xiaomi's R&D intensity was 3.5 percent in 2020 and Lenovo's 2.63 percent. In both cases, that figure was lower than the previous year.

Generally, hardware companies do tend to invest less in R&D than do their more software-focused counterparts: Xiaomi and Lenovo might therefore not be comparable to Facebook, Amazon, and Google – or to Baidu, Alibaba, Tencent, and JD. But the closest US analog to Xiaomi and Lenovo, Apple, boasts an R&D intensity almost two times as high as Xiaomi's: In 2020, Apple's R&D expenses totaled 6.83 percent of its revenue, a ten-year high. Moreover, Apple's R&D intensity has grown every year, and grown significantly over the past decade, while Xiaomi and Lenovo's have remained steady or decreased.

Figure 7: Apple, Xiaomi, Lenovo, JD R&D and R&D Intensity (2012-2019) (RMB mn)[31]



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[30] Data collected from company annual reports, WIND Data; similar data also discussed in: "数据会说话：定位中国硬核科技公司 [Data Speaks: Positioning Chinese Hardcore Technology Companies]," IYIOU, February 1, 2001.

[31] Data collected from company annual reports, WIND Data; similar data also discussed in: "数据会说话：定位中国硬核科技公司 [Data Speaks: Positioning Chinese Hardcore Technology Companies]," IYIOU, February 1, 2001.

Synthetic: Platforms and Infrastructures

The next stage of this analysis seeks to benchmark relative capacity in the physical and virtual infrastructures necessary to apply emerging S&T capacity at scale; the networks and platforms according to which technologies are deployed internationally. Technological advances have created a world defined by exchange. That exchange takes place on, and shaped by, cross-border networks and platforms, whether telecommunications or rail networks, social media or e-commerce platforms. These networks and platforms are key to international competition. They define how, where, and whether goods, people, and information move.

Commentators in both the US and China have recognized as much. These infrastructures are the systems that Lei Shaohua described as critical for reaping the benefits of high technology – and argued that free market systems risked failing to supply.[32] In Fall 2020, Eric Schmidt, Jared Cohen, Richard Fontaine, Liz Economy, and Alexandr Wang – leading figures in the US technology and security communities – proposed an outline for strategic competition with China in technology. Their recommendations began with a focus on "platform competition:" "Platform dominance is a crucial aspect of competition with China."[33]

Beijing's industrial policy prioritizes networks and platforms, the capital expenditures necessary to fund them, and the industrial agglomeration necessary efficiently to develop them. Since 2018, the PRC has emphasized a set of "new infrastructures," including 5G base stations, UHV networks, high-speed rail and urban rail, new energy vehicle charging stations, big data centers, space infrastructures, and the industrial Internet.[34] The phrase "new infrastructure" refers to those networks and platforms necessary to support large-scale application of emerging industries comprise the systems. In March 2020, the Standing Committee of the Political Bureau of the CPC Central Committee convened a meeting about accelerating the construction pace of new infrastructures.[35] The State Council Government Work Report published May 2020 proposed a focus on supporting the construction of new infrastructure.[36] And the 14th Five Year Plan devoted a section to "speeding up the construction of new infrastructure."[37]

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[32] Lei Shaohua, "超越地缘政治: 产业政策与大国竞争["Beyond Geopolitics: Industrial Policy and Great Power Competition]." *World Economy and Politics*, 2019 (5).

[33] China Strategy Group, "Asymmetric Competition: A Strategy for China and Technology," Fall 2020. https://www.documentcloud.org/documents/20463382-final-memo-china-strategy-group-axios-1

[34] "解读：中央经济工作会议定义'新型基础设施建设' [Interpretation: The Central Economic Work Conference Defines 'New Infrastructure Construction']," Guizhou Provincial Comprehensive Information Network, January 11, 2019. For additional, informal context on new infrastructures, see the Baike page for 新型基础设施建设 [new infrastructures].

[35] "新型基础设施建设中蕴藏哪些新动能？[What New Kinetic Energy Is Contained in the Construction of New Infrastructure?]," *Xinhua News*, March 8, 2020.

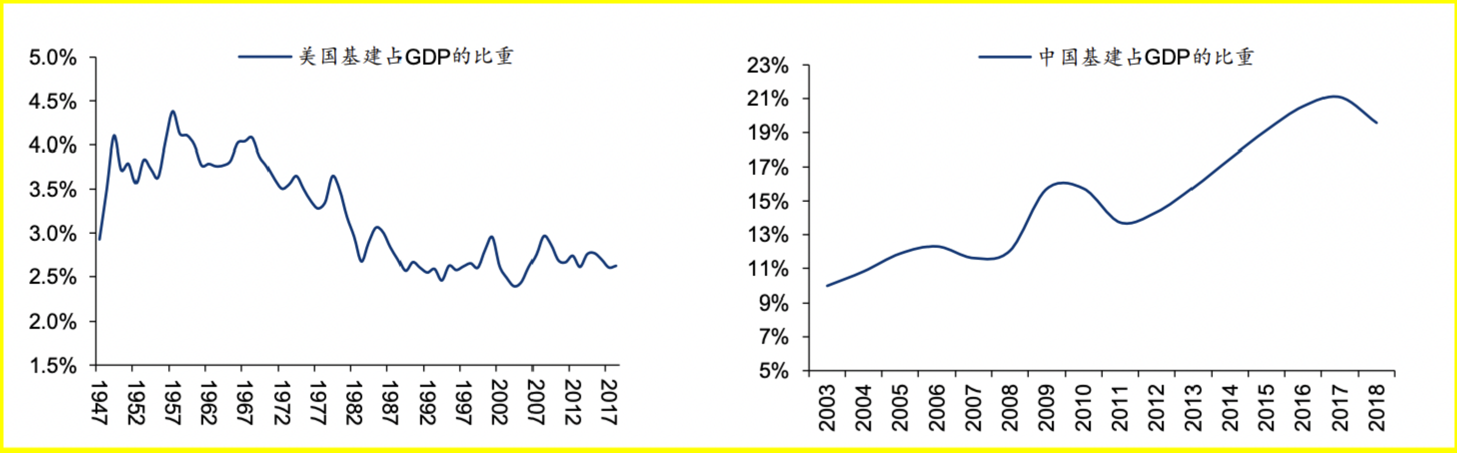
[36] "新基建首次写入政府工作报告，七大关键领域释放新一轮红利 [The New Infrastructure Was Written into the Government Work Report for the First Time, and the Seven Key Areas Released a New Round of Dividends]," *Xinhua News,* May 31, 2020.

[37] Pointing in particular to 5G networks, IPv6, Internet of Things, big data centers, supercomputing centers, the industrial Internet and the Internet of Vehicles, space infrastructure. (See: "Translation: Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035," Center for Security and Emerging Technology, May 12, 2021. https://cset.georgetown.edu/wp-content/uploads/t0284_14th_Five_Year_Plan_EN.pdf

With some delay, US policy has begun to place a parallel emphasis on emerging technology-relevant infrastructure. The one trillion USD infrastructure bill advanced by the Biden Administration includes 7.5 billion USD for construction of national EV charging infrastructure and 65 billion USD for high-speed internet.[38]

General resource allocations suggest that China assigns greater emphasis to infrastructure, broadly, than does the United States: The Chinese public and private sector invested some 17.62 trillion RMB in infrastructure construction in 2018, about 4.7 times the US figure of 548.4 billion USD.[39] That difference is even greater for investment as a share of GDP: China's infrastructure investment accounted for 20 percent of its GDP in 2018 and 21 percent in 2017. US infrastructure investment as a share of GDP has dropped from around 4 percent to around 2 percent since the 1950s. It stood at 2.62 in 2018.[40]

Figure 8: US and Chinese Infrastructure Investment as a Share of GDP[41]



These high-level figures are useful for the general context they provide. However, they are limited in their value and applicability to this particular case. First of all, they refer to infrastructures broadly, not to the high-tech ones on which this assessment is focused. Second, they assume a common – or at least generally common – definition of infrastructure, though no such definition exists. Third, they do not account for the two countries' different stages of development.

Specific case studies offer additional insight, geared specifically toward the high-tech case. This section explores two cases: Electric vehicle (EV) charging infrastructure and satellite networks. These cases were selected for their, slightly different, places in Chinese and US industrial and technological policy. EVs and

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[38] "Fact Sheet: Historic Bipartisan Infrastructure Deal," The White House, July 28, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/07/28/fact-sheet-historic-bipartisan-infrastructure-deal/

[39] Bao Ronfu et al., "中美日基建投资现状及历史比较 [China, the United States and Japan's infrastructure Investment Status and Historical Comparison]," Huatai Securities, October 27, 2019.

[40] Ibid.

[41] Bao Ronfu et al., "中美日基建投资现状及历史比较 [China, the United States and Japan's infrastructure Investment Status and Historical Comparison]," Huatai Securities, October 27, 2019.

satellite networks figure in China's major innovation and infrastructure construction efforts, suggesting a focus that extends from technological development to application. US innovation programs also emphasize both EVs and space. However, only the former appears in major new US infrastructure programming (see table).

Table 4: EVs and Satellites in US and Chinese S&T Policy

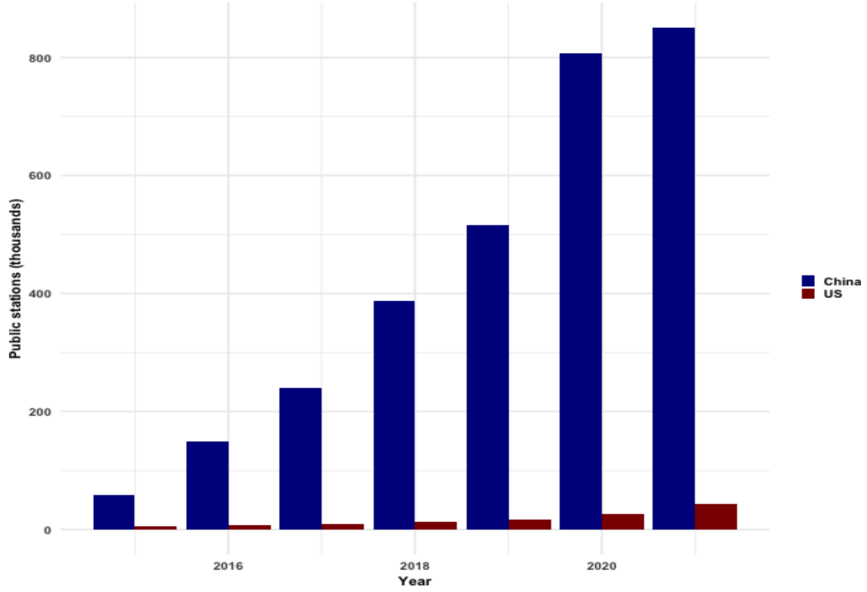
	14th Five Year Plan Focus Area	"New infrastructure"
Electric vehicles	√	√
Space satellites	√	√

	US Innovation and Competition Act	Infrastructure Investment and Jobs Act
Electric vehicles	√	√
Space satellites	√	×

Electric Vehicle Charging Stations

US EV charging infrastructure – and pace of construction -- pales next to China's. In 2015, China had some ten times as many public charging stations as did the US. Today, China has almost twenty times more. The US government has recognized this efficiency. Development of EV infrastructure has been a key talking point for the Biden Administration.[42] And the 2021 Senate bipartisan infrastructure package allocates 7.5 billion USD to

Figure 9: EV public charging stations, by country over time



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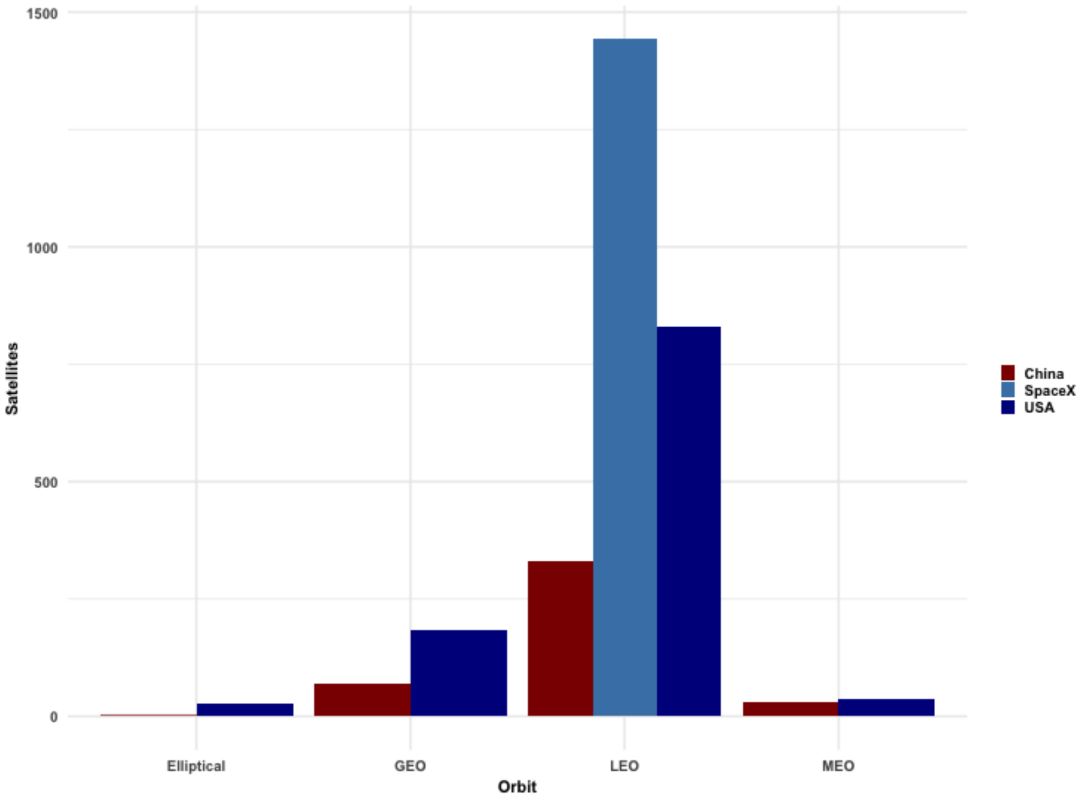
[42] Tina Bellon, "Biden Infrastructure Plan Takes on EV Charging's Inequality Problem," *Reuters*, September 1, 2021. https://www.reuters.com/world/us/biden-infrastructure-plan-takes-ev-chargings-inequality-problem-2021-09-01/.

[43] "Federal Money for EV Charging Isn't Nearly Enough," *Autoweek*, August 23, 2021. https://www.autoweek.com/news/a37372003/federal-money-for-ev-charging-wont-be-enough/.

Space Satellites

At first glance, a reverse picture holds for space satellites. The US owns or operates[44] almost six times as many satellites in orbit as does China: 2,520 to 431. That quantitative advantage applies across types of orbit. The greatest advantages for the US lie in elliptical orbits (28 to 2) as well as – thanks in part to SpaceX's 1,442 low earth orbit (LEO) satellites – LEO (2,273 to 331).[45]

Figure 10: US and China overall satellite count, by orbit[46]



Orbit	China	US
Elliptical	2	28
GEO	69	183
LEO	331	2273
MEO	29	36

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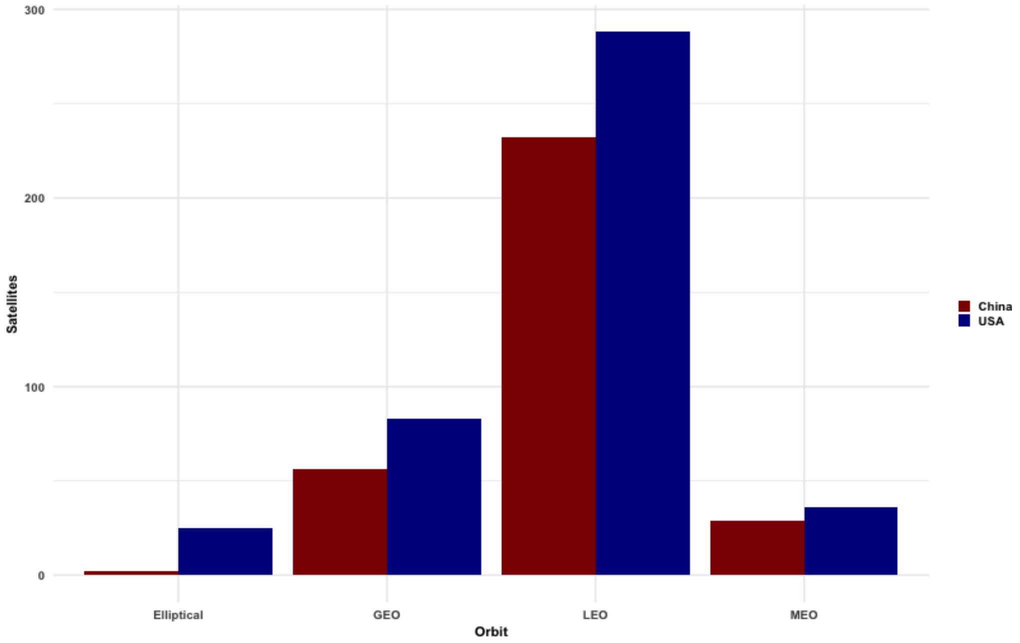
[44] In part or in full: US-foreign-owned or -operated satellites (e.g., the Perseus M1 and M2, operated by the RNC Strategic Resources Fund's Dauria Aerospace and jointly contracted by Dauria and Canopus Systems) are included in this assessment. So are Sino-foreign satellites (e.g., CFOSat, jointly operated by the China National Space Administration and France's National Centre for Space Studies).

[45] This data, and all other satellite data, comes from the UCS Satellite Database, accessed August 1, 2021. https://www.ucsusa.org/resources/satellite-database

[46] This data, and all other satellite data, comes from the UCS Satellite Database, accessed August 1, 2021. https://www.ucsusa.org/resources/satellite-database

The US numerical satellite advantage is primarily a function of commercial-use satellites: The US owns or operates some 2,204 commercial-use satellites; China 117.[47] If those satellites with purely commercial applications are taken out of the equation and one looks only at satellites with civil, governmental, or military uses, the US and China sit at near numerical parity overall, 432 to 319.[48] And in certain sub areas, China's numerical capacity exceeds that of the US: China boasts 215 satellites with government applications to the US's 181.

Figure 11: Non-commercial use satellites, by orbit and country of ownership



In other words, based on an overall count, the commercial space strength of the United States far exceeds China's. However, the respective powers' government and military arsenals sit at relative parity.

Table 5: US and Chinese satellites, by use case and orbit[49]

	US Satellite Count				Chinese Satellite Count			
Class	**Civil**	**Commercial**	**Gov**	**Military**	**Civil**	**Commercial**	**Gov**	**Military**
Elliptical	3	3	10	13			2	
GEO		102	15	68		18	49	23
LEO	63	2065	156	101	24	99	135	73
MEO		34		36			29	29
Overall	66	2204	181	218	24	117	215	125

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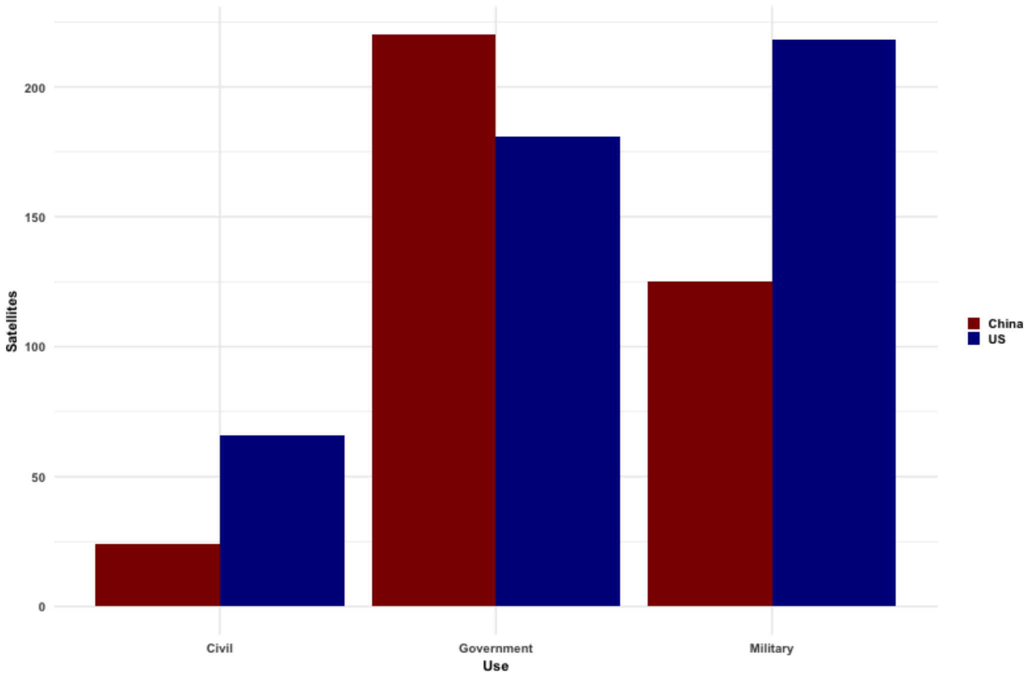
[47] This tally includes all satellites with commercial users, including those that serve dual purposes (e.g., commercial and government).

[48] This tally includes all satellites with government, military, or civil users, include that serve dual purposes (e.g., commercial and government).

[49] Satellites are double counted where they have multiple uses (e.g., a satellite being used for military and commercial purposes is counted here as both military and commercial).

Figure 12: Non-commercial use satellites, by application and country of ownership[50]



Asymmetries of Control

Moreover, parsing only by use case may underestimate the degree of overall control that Beijing has over its constellation of satellites – and the corresponding asymmetry vis-à-vis the US. Most of the satellites owned by Chinese entities, both commercial and otherwise, are owned, operated, and contracted by State-owned players, and by a consolidated set thereof. Many of those State-owned players, which include companies and universities, have ties to the Chinese military apparatus. For example, almost 70 percent of China's satellites are contracted to CASC, a Chinese State-owned defense conglomerate that the US Department of Defense has identified as tied to the Chinese military. The reverse holds for the US. Most satellites owned by US entities are for commercial use; owned, operated, and contracted by commercial players without government ownership – and that may even have ties to the Chinese government.

Table 6: US and Chinese Government-Owned and -Contracted Satellites by Type of Orbit[51]

		Elliptical	GEO	LEO	MEO	Overall
US	Government-owned owner	25	82	214	36	357
	Government-owned contractor	16	12	122	2	152
China	Government-owned owner	2	62	249	29	342
	Government-owned contractor	2	59	269	29	359

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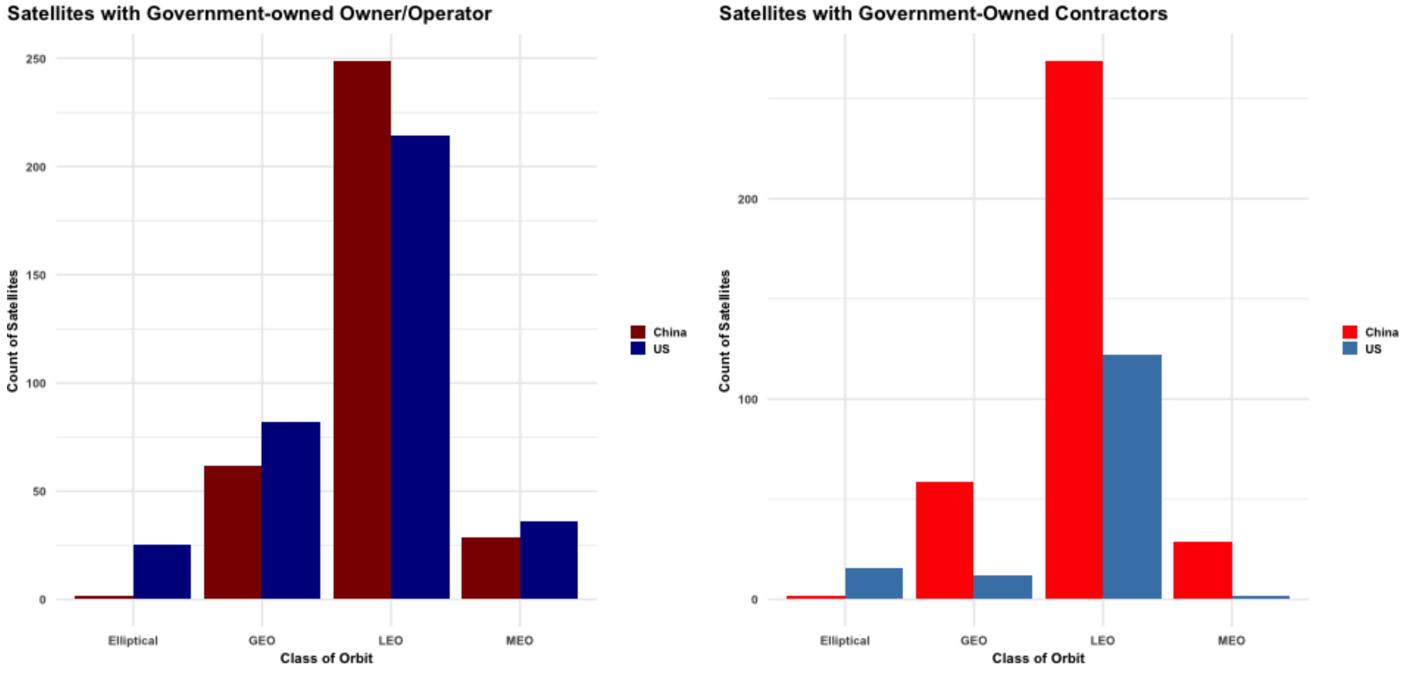
[50] See footnote 49.

[51] Satellites with joint government-private ownership or contracting are included in this tally.

Figure 13: Satellites operated and contracted by government entities, by country and orbit



The charts and tables above lay out the relative numerical balance for satellites owned and operated by government-owned players. The reciprocal of this picture might be more compelling: Only 70 total Chinese satellites are owned exclusively by private players. 2,356 US satellites are. And the categorization methodology used here is a generous one for the US: It treats US public research institutions (e.g., California Polytechnic University) as government-owned players akin to Chinese research institutions (e.g., Tsinghua University, Chinese Academy of Sciences) – though Beijing exerts far more control over its network of research institutions than does Washington.

The degree of Chinese government control over the satellite ecosystem is also evident in the relevant players' consolidation – especially compared to a fragmented US playing field. The three main contractors for China's satellites account for more than 85 percent of the total. China Aerospace Science and Technology Corporation (CASC), including its subsidiaries, alone accounts for 69.84 percent of China's satellites; the Chinese Academy of Sciences and its subordinate institutions 12.53. Both are State-owned players with close ties to Beijing's military and military-civil fusion apparatus. Meanwhile, the three main contractors for US satellites account for less than 70 percent of the total. SpaceX tops the list with 57.22 percent, or 1,442 satellites, followed by Google-backed Planet Labs with about 7 percent, or 178 satellites. Both of those are private companies.

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[51] Satellites with joint government-private ownership or contracting are included in this tally.

Table 7: Top satellite contractors

PRC parent	Total	Percent of total	US parent	Total	Percent of Total
CASC	301	69.84	**SpaceX**	1442	57.22
Chinese Academy of Sciences	54	12.53	**Planet Labs**	178	7.06
Zhuhai Orbita Control Engineering	12	2.78	**Spire Global**	115	4.56
Guodian Gaoke	10	2.32	**Thales**	104	4.13
Spacety	10	2.32	**Lockheed Martin**	87	3.45

The high rank of Thales on the list of US satellite contractors points to an additional asymmetry between the US and Chinese constellations. Only one Chinese satellite is wholly contracted to a foreign entity: Asiasat 3SA, launched in 1999, owned by Asia Satellite Telecommunications Co. Ltd. and with Boeing as the contractor. By contrast, at least 109 US satellites are, including the Global Change Observation Mission – 1, a joint project with Japan launched in 2012, contracted to and owned by the Japan Aerospace Exploration Agency. The United States also has two satellites jointly launched with Russia in 2014, contracted to both Russia's Dauria Aerospace and US Canopus Systems but owned/operated by Dauria. Dauria is a portfolio company of I2BF-RNC Strategic Resources Fund, an investment fund created jointly by RUSNANO Capital and I2BF Holdings Ltd. The Fund is dedicated to the transfer to Russia of technologies related to the provision of strategic resources.[52]

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[52] Private sector entities could also be included within the scope of the supporting infrastructure for technological development. Within such a framing, benchmarking US versus Chinese strengths would suggest a dynamic similar to that in satellites: As discussed earlier in this report, the US tech sector is multiple times larger than China's. However, Beijing's control over its tech sector far exceeds that of the US government.

Downstream: Standards

This final section seeks to benchmark relative influence over international technical standards. Technical standards are established norms or requirements for engineering or technical criteria. They are the rules according to which technologies are applied – and that, when applied across borders, permit interoperability of those technologies. Examples of technical standards range from fifth generation telecommunications (5G) to voltage for electronic equipment, rail gauges to auditing practices.

Technical standards influence how technological domains evolve, as well as the commercial hierarchy within them. For example, the 5G standard that is adopted internationally will determine everything from how far apart base stations sit to how information is shared across the telecommunications network, as well as those systems that the network supports. The country or countries, company or companies, that are able to shape key elements of this standard will be able to determine how the corresponding technology develops. They will also claim a competitive advantage in relevant commercialization: Their systems will be compatible with the globally adopted standard and their technologies developed for it. US leadership in 4G is estimated to have accounted for approximately 125 billion USD in revenue for US companies in 2016.[53]

With what is widely accepted as a S&T revolution under way, a new generation of standards is currently taking form. These are poised to shape the future technological environment and the competitive hierarchy within it. They are also likely to do so in an enduring fashion. Technical standards are enduring. These rulesets tend to be locked in by both large-scale capital expenditure and the inertia of international coordination. As a result, the influence and competitive advantage that setting technical standards bestows tend to last.

As Liu Pingping, director of the Standardization Administration of China (SAC), put it in 2006, "patents affect only one or several companies, while standards affect the competitiveness of industries and even countries."[54] SAC's "2008 Key Points for National Standardization Work" explain that Beijing seeks international standards influence "so that China's leading enterprises will truly lead the entire global industry and lead the future." Or, per Xi Jinping in 2016, "standards lead the progress of the times."[55]

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[53] "How America's 4G Leadership Propelled the American Economy," Recon Analytics, April 16, 2018. https://api.ctia.org/wp-content/uploads/2018/04/Recon-Analytics_How-Americas-4G-Leadership-Propelled-US-Economy_2018.pdf

[54] 中国创造呼唤中国标准 标准战略上升为国家意志 [China's Innovation Calls for China's Standards. Standards Strategy Has Become the Will of the Country], Xinhua News, April 28, 2006.

[55] 中国将积极实施标准化战略 [China Will Actively Implement the Standardization Strategy], Nanjing Daily, September 13, 2016.

Asymmetric Emphasis

As those quotations suggest, Beijing has prioritized standards, and international standard-setting influence, for decades.[56] In 2001, the PRC established the SAC which promptly launched the National Standardization Development Project.[57] Issued in 2006, the National Medium and Long-Term Program for Science and Technology Development（2006-2020）(MLP) proposed to "implement an intellectual property strategy and a technical standard strategy;" that same year, the 11th Five Year Plan outlined over a dozen new requirements for standardization work.[58] Liu Pingping framed the place of standards in Chinese policy succinctly in 2006: "The standard strategy has risen to the will of the country."[59]

Beijing's strategic emphasis on standards only increased over the next fifteen years. In 2015, the State Council issued the Notice on Issuing the Reform Plan for Deepening Standardization Work, (hereafter the Notice)[60] which included a provision to "encourage the level of internationalization of standards" and called for "using the Go Out of Chinese standards to drive China's products, technologies, equipment, and services to Go Global." Building on the Notice, in 2015, the State Council issued the National Standardization System Construction and Development Plan (2016-2020) (hereafter Development Plan).[61] That document declared that:

> By 2020, China's standards international influence and contribution [will] have greatly increased, and China [will have] entered the ranks of the world's standards powers.... The ability to participate in international standardization activities [will have] been further strengthened…mutual recognition of standards with major trading partners [will be] progressing steadily…"[62]

The Development Plan included a dedicated Chinese Standards Go Out Major Project stressing a set of standards areas for internationalization. These align closely with Beijing's technological innovation priorities and strategic emerging industries: They include energy conservation, next-generation information technology, high-end equipment manufacturing, new energy, new materials, and new energy vehicles. The Development Plan also emphasized that internationalization of Chinese standards would demand increasing, and leveraging, Chinese influence over international standardization organizations.[63]

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[56] For additional discussion see: Emily de La Bruyere, "China's Quest to Shape the World through Standards Setting," The Hinrich Foundation, July 13, 2021. https://www.hinrichfoundation.com/research/article/tech/china-quest-to-shape-the-world-through-standards-setting/

[57] Xu Feng, "中国国家标准化管理委员会在京成立 [Standardization Administration of China Was Established in Beijing], *China Quality and Technical Supervision*, 2001; 国家标准委正在制定'国家标准化发展纲要' [The National Standards Committee is formulating the 'National Standardization Development Program'], *Standardization and Quality of the Machinery Industry*, 2002 (10).

[58] 中国创造呼唤中国标准 标准战略上升为国家意志 [China's Innovation Calls for China's Standards. Standards Strategy Has Become the Will of the Country], Xinhua News, April 28, 2006.

[59] Ibid.

[60] 国务院关于印发深化标准化工作改革方案的通知 [Notice of the State Council on Issuing the Reform Plan for Deepening Standardization Work], State Council, March 11, 2015.

[61] 国家标准化体系建设发展规划（2016-2020年）[National Standardization System Construction and Development Plan (2016-2020)], State Council, December 30, 2015.

[62] Ibid.

[63] Ibid.

The next year, in his 2016 letter to the ISO's 39th International Standardization Organization Conference, Xi Jinping declared that "China will actively implement a standardization strategy."[64] That was no empty promise. In 2018, the SAC launched a two-year China Standards 2035 research program, led by the China Academy of Engineering, intended to support the development of a national standards strategy.[65]

The US has not, in recent history, maintained the same emphasis on standards as tools of national technological power. Instead, standard-setting has remained largely under the purview of private sector interests – and been left out of assessments of national strength. However, growing recognition of China's standards strategy is beginning to change that. In May 2019, Senator Roger Wicker of Mississippi introduced the United States 5G Leadership Act of 2019 which included a section dedicated to "promoting United States leadership in communications standard-setting bodies."[66] President Biden has called for the US to grow more involved in international standard-setting in order to offset China's increasing influence.[67] And the US Innovation and Competition Act (USICA) passed by the Senate in June 2021 includes six provisions dedicated to US leadership in technical standards.[68] Still, the US lacks any empowered coordination body for international standard-setting, where China has had one for decades.

Measuring Standards Influence

International standard-setting bodies have historically played a critical role in shaping global technical standards. The largest of these bodies are the International Standardization Organization (ISO), International Electrotechnical Commission (IEC), and International Telecommunications Union (ITU). This analysis focuses on benchmarking relative influence in those three organizations – both because they are critical international fora for standard-setting and because Beijing's standards strategy has identified them as such. Two decades worth of SAC annual planning documents describe intentions to increase Chinese influence in the ISO and IEC as well, if to a lesser extent, the ITU.[69] For example, the SAC's 2008 Key Points of National Standardization Work calls for "expand[ing] the number of P-members [participating members] in ISO technical committees or sub-committees."[70] And the State Council's 2015 Development Plan notes that: "Chinese experts hold a series of important positions such as ISO Chairman, IEC Vice Chairman, and ITU Secretary General, and the number of international standards of which China leads the formulation is increasing year by year."[71]

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[64] 中国将积极实施标准化战略 [China Will Actively Implement the Standardization Strategy], Nanjing Daily, September 13, 2016.

[65] "'中国标准2035'项目结题会暨'国家标准化发展战略研究'项目启动会在京召开 ['China Standard 2035' Project Closing Meeting and 'National Standardization Development Strategy Research' Project Kick-Off Meeting Was Held in Beijing]", Standardization Administration of China, January 15, 2020.

[66] S.1625 - United States 5G Leadership Act of 2019, https://www.congress.gov/bill/116th-congress/senate-bill/1625/text

[67] Laurie Clarke, "Technical standards-setting is shaping up to be the next China-US showdown," *Tech Monitor*, June 15, 2021. https://techmonitor.ai/technology/technical-standards-setting-shaping-up-next-china-us-showdown

[68] Mark Montgomery, Natalie Thompson, "What the U.S. Competition and Innovation Act Gets Right About Standards," *Lawfare*, August 13, 2021. https://www.lawfareblog.com/what-us-competition-and-innovation-act-gets-right-about-standards

[69] For more in depth analysis on the subject, see Emily de La Bruyere,"China's Quest to Shape the World through Standards Setting," The Hinrich Foundation, July 13, 2021. https://www.hinrichfoundation.com/research/article/tech/china-quest-to-shape-the-world-through-standards-setting/

[70] Standardization Administration of China, "2008年全国标准化工作要点 [2008 Key Points of National Standardization Work], 2008.

[71] 国家标准化体系建设发展规划（2016-2020年）[National Standardization System Construction and Development Plan (2016-2020)], State Council,

Existing US analysis of relative leverage in standard-setting bodies – a small, but growing body of work – tends to focus on the highest-level leadership positions; on the Chinese presidencies of the ITU and IEC, and the long-time Chinese leadership of the ISO.[72] But those high-level positions only tell part of the story. The individuals who actually oversee the granular goings-on in international standards bodies are the leaders of specific technical committees and working groups. Chinese planning has consistently emphasized the importance of these lower-level roles, as well as of membership pure and simple.[73] This analysis benchmarks Chinese membership count as well as leadership posts in working groups, technical committees, and subcommittees across ISO, IEC, and ITU.

International Standardization Organization

The International Standardization Organization (ISO) is a global standard-setting body composed of representatives – one per country – from various national standards organizations. The ISO has general consultative status with the United Nations Economic and Social Council and is charged with developing and publishing international technical, industrial, and commercial standards.[74]

At ISO, the American National Standards Institute (ANSI), a private non-profit based in New York, represents the US. The Standardization Administration of China (SAC), a government entity administered by the General Administration of Quality, Supervision, Inspection, and Quarantine (AQSIQ), represents China.[75]

The ISO's work is carried out by 256 technical committees; groups of experts that together develop and publish standards within their particular sectors. The technical committees cover everything from information technology to sex toys. Every technical committee has a Secretariat, held by a single ISO member, as well as an individual committee manager and chairperson. In most cases, both the committee manager and the chairperson of a given technical committee are from the same country as its Secretariat.[76]

Today, ANSI, representing the US, holds secretariat positions over 31 ISO technical committees; SAC, representing China 33. The only member country to hold more secretariat positions is Germany's Deutsches Institut für Normung (DIN), with 38.

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[72] See, for example, Bradley Thayer and Lianchao Han, "We cannot let China set the standards for 21st century technologies," *The Hill*, April 16, 2021.

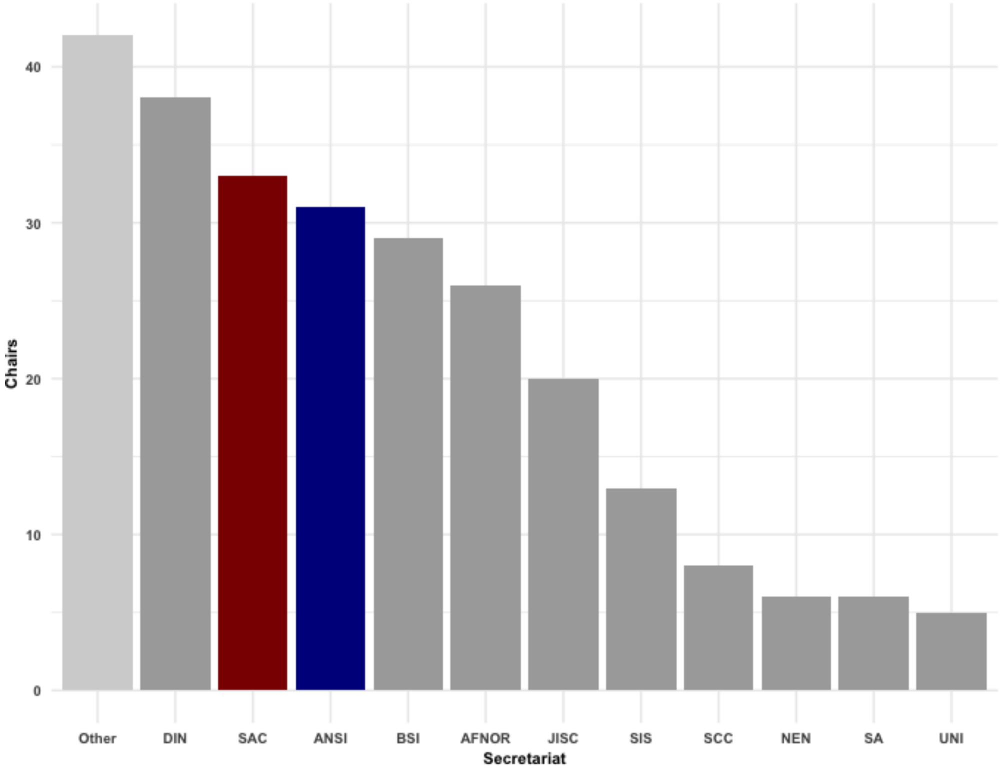
[73] Emily de La Bruyere,"China's Quest to Shape the World through Standards Setting," The Hinrich Foundation, July 13, 2021. https://www.hinrichfoundation.com/research/article/tech/china-quest-to-shape-the-world-through-standards-setting/

[74] "About Us," International Standardization Organization, https://www.iso.org/about-us.html.

[75] "Members," International Standardization Organization, https://www.iso.org/about-us.html.

[76] This, and all other data on ISO technical committees, comes from "Technical Committees," International Standardization Organization, https://www.iso.org/technical-committees.html.

Figure 14: ISO Secretariat Positions, by Member Country[77]



However, not all technical committees can be considered equal. They have different levels of activity – and, of course, exist in fields with different degrees of strategic significance. For example, the ANSI-led information technology technical committee has published 3,293 standards and has another 557 currently under development. By contrast, the SAC-led light gauge metal containers technical committee has only published 9 standards, with three under development and the SAC-led lithium technical committee has never published any standards.

Weighting technical committees by the total number of standards that they have developed – or those currently under development – suggests a very different competitive picture. ISO technical committees under ANSI's leadership have published 6,244 standards and currently have 1,155 underway. For SAC, those figures sit at 2,025 and 414 respectively. This leap for the US is largely a product of ANSI's secretariat position over the information technology technical committee, a joint committee with the IEC. The appendix to this report includes the lists of all technical committees of which ANSI and SAC hold secretariat positions.

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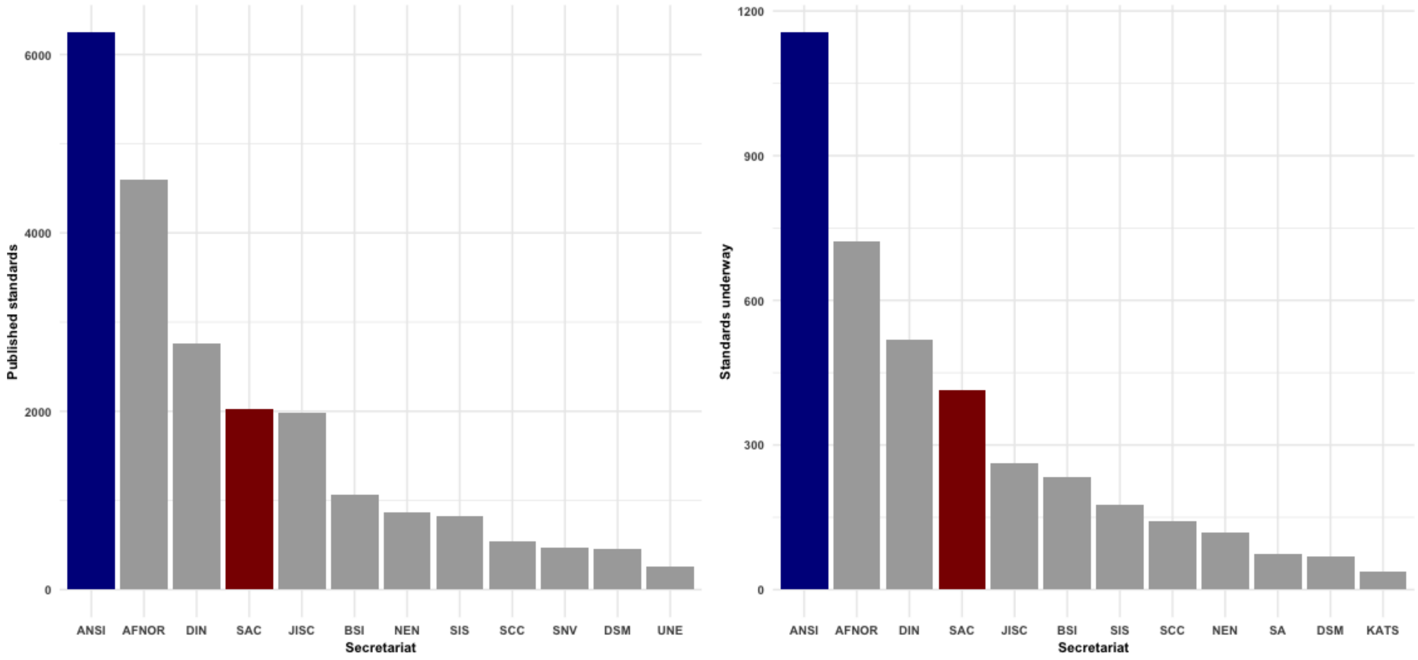
[77] This chart only includes the 12 countries with the greatest number of Secretariat positions. This, and all other data on ISO technical committees, comes from "Technical Committees," International Standardization Organization, https://www.iso.org/technical-committees.html.

Figure 15: Standards Published and Under Development by Secretariat Country[78]



International Electrotechnical Commission (IEC)

The International Electrotechnical Commission (IEC) prepares and publishes international standards for all electrical, electronic, and related technologies. These cover everything from power generation to home appliances, semiconductors to batteries, solar energy to nanotechnology. The IEC is composed of national committees from its member countries, made up of manufacturers, providers, consumers, distributors and vendors, governmental agencies, trade associations, and representatives from national standards bodies.[79]

The US and Chinese national committees at the IEC are roughly equivalent in size: The US has a total of 173 full-participating members (known as P-members) and China 189. In total, there are 3,972 ISO P-members from 81 countries. The chart below shows total member count for the eight largest national committees.[80]

As with the ISO, the IEC's work is carried out by technical committees. There are 111 in total, as well as 95 subcommittees subordinate to them, with focuses ranging from stabilized power supplies to information technology, UHV AC transmission systems to motor-operated electric tools. As with the ISO, these technical committees have national secretariats.[81]

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[78] This chart only includes the twelve countries with the greatest number of Secretariat positions.

[79] "About Us," International Electrotechnical Commission, https://www.iec.ch/about-us.

[80] This, and all other data on national committee members, comes from "National Committees," International Electrotechnical Commission, https://www.iec.ch/national-committees.

[81] This, and all other data on IEC technical committees and subcommittees, comes from "Technical Committees and Subcommittees," International Electrotechnical Commission, https://www.iec.ch/technical-committees-and-subcommittees#tclist.

Figure 16: IEC National Committees by Number of Participating Members[82]

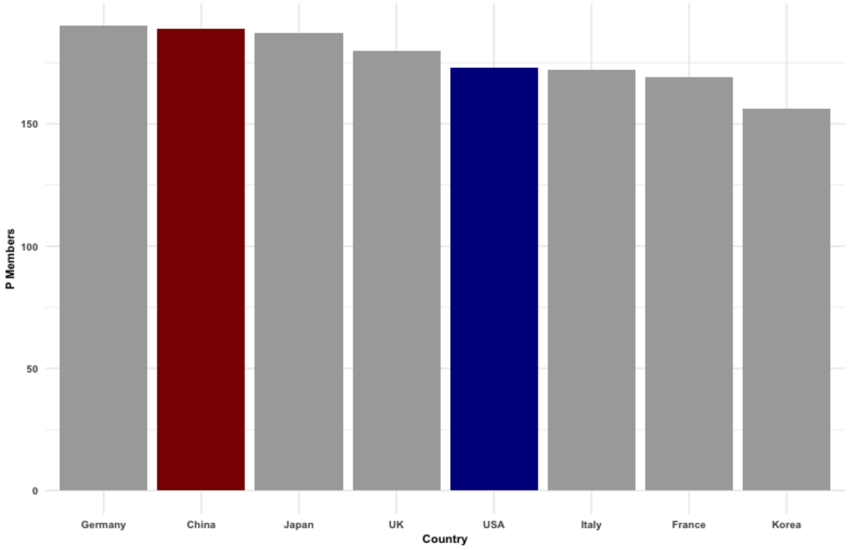
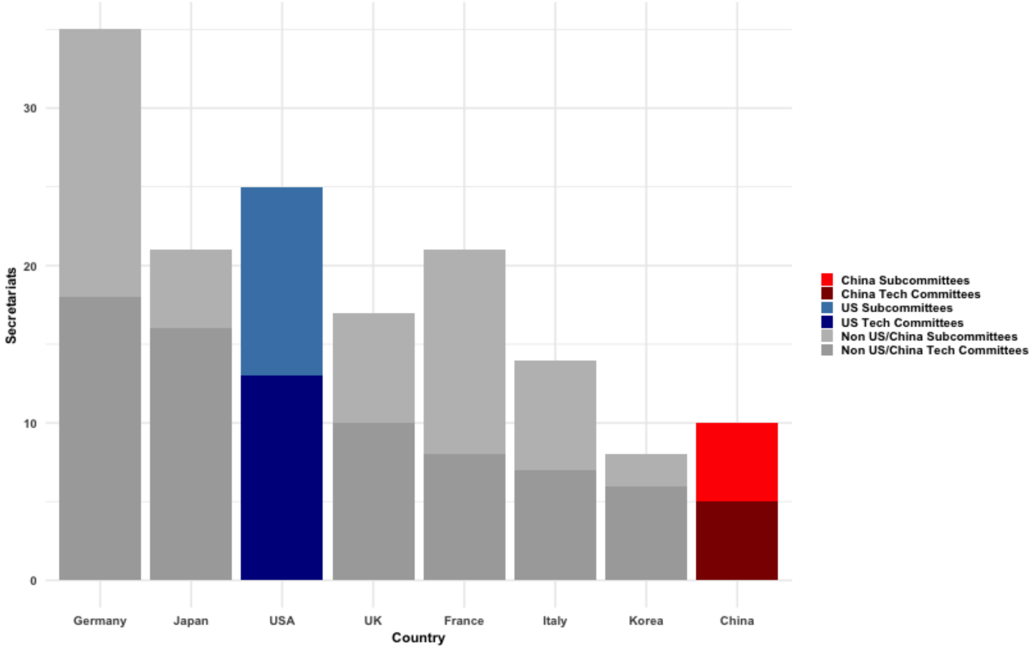


Figure 17: Secretariat Positions in IEC Technical Committees and Subcommittees, by Country[83]



But unlike in the ISO, the US holds far more secretariat positions in the IEC than does China, 13 to five. In addition, the US holds secretariat positions in twelve subcommittees, compared to five for China. Neither country leads the IEC as a whole: Germany and Japan both have more technical committee secretariat

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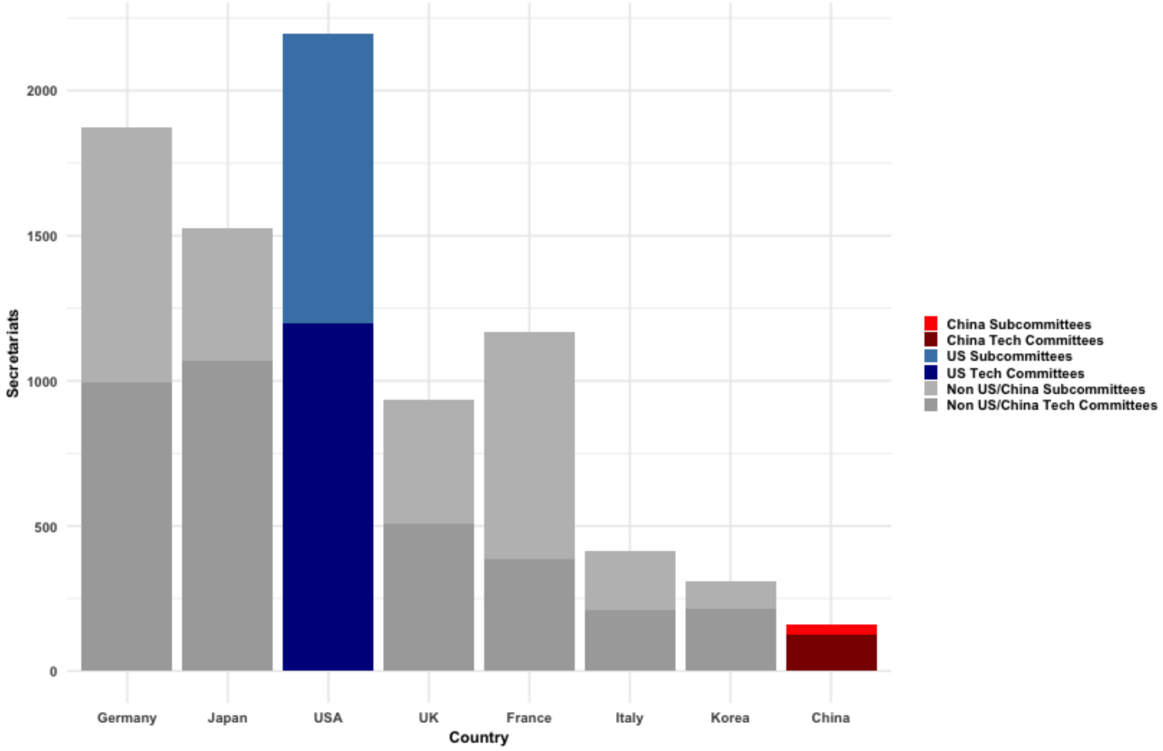
[83] This chart only includes the eight countries with the largest number of P-members. This, and all other data on IEC technical committees and subcommittees, comes from "Technical Committees and Subcommittees," International Electrotechnical Commission, https://www.iec.ch/technical-committees-and-subcommittees#tclist.

[82] This, and all other data on national committee members, comes from "National Committees," International Electrotechnical Commission, https://www.iec.ch/national-committees.

positions than either the US or China (18 and 16, respectively); Germany and France more subcommittee secretariat positions (17 and 13, respectively).

Still, again, these committees cannot be considered equal: They deal with different fields and at different levels of activity. And again, weighting by total number of standards that a given committee has published strengthens the US hand considerably, while diminishing China's. To avoid duplication with the previous section, this analysis does not account for the US secretariat position in the joint ISO/IEC technical committee on information technology.

Figure 18: IEC Standards Published and Under Development by Secretariat Country[84]



International Telecommunications Union

The International Telecommunications Union (ITU) is the United Nations specialized agency responsible for information and communication technologies (ICTs). The ITU allocates global radio spectrum and satellite orbits, develops technical standards to ensure interconnectivity and interoperability of international ICT systems, and works to improve access to ICTs across the developing world.[85] The ITU's membership is broader than that of the ISO and IEC. It includes hundreds of individual members representing the government, private, and academic sectors. This makes it a more interesting and multidimensional case for analysis – both because there is more room for disparity and because the organization offers a window into the differing roles and natures of the US and Chinese private sectors in the standard-setting process.

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[84] This chart only includes the eight countries with the largest number of P members.

[85] "About International Telecommunications Union," International Telecommunications Union, https://www.itu.int/en/about/Pages/default.aspx.

The ITU is divided into three Sectors: The Radiocommunication Sector (ITU-R) which coordinates global radiocommunications services and manages radio-frequency spectrum and satellite orbits; the Telecommunication Standardization Sector (ITU-T), charged with developing telecommunications-relevant standards; and the Telecommunication Development Sector (ITU-D), dedicated to supporting development efforts to improve global access to ICTs.[86]

The bulk of the ITU's work is carried out in study groups and their subordinate work programs, charged with establishing technical standards or guidelines in specific areas. As of their most recent published counts,[87] ITU-R has six study groups ranging from spectrum management to terrestrial services; ITU-T eleven ranging from security to IOT, smart cities, and communities; ITU-D two.[88] In addition, ITU also operates focus groups – more dynamic fora designed to address urgent, emerging, market-oriented industry issues outside of the purview of existing study groups. Focus group areas include quantum information technology for networks and artificial intelligence for natural disaster management.

ITU Membership

The 193 UN member states are all ITU member states. In addition, companies and organizations (e.g., research institutes, regional organizations) can, for a fee, become members of one or more ITU Sectors – as sector members, associate members, or academia members. Associate members are limited in their participation to single study groups, where sector and academic members have access to all study groups and the full range of a sector's activity.[89] There are 915 ITU members affiliated with a country, 519 of them sector members, 243 associate, and 153 academic.[90] Across the first two categories, the US has more members than does China – and, in fact, more than does any other player, with 64, 48, and 10, respectively, compared to 31, 25, and 24 for China.

These counts may slightly underestimate the extent of Chinese representation at ITU. Members are categorized by the country in which they are headquartered, not the country of their parent entity. Some Chinese-owned member entities are classified as non-Chinese. For example, at least five Huawei entities are ITU members, but all claim different national affiliations: Huawei Technologies, Shenzhen (China), Huawei Technologies Dusseldorf (Germany), Huawei Technologies Sweden (Sweden), Huawei Technologies Switzerland (Switzerland), and Futurewei Technologies US R&D Center (USA). This is not unique to Huawei or China. Deloitte Risk Advisory Milano, a sector member of ITU-D, is classified as Italian although Deloitte itself is a US company; Ericsson Canada as a Chinese entity. But no company is as widely represented in the ITU with as broad a range of national affiliations as is Huawei.

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[86] "What We Do," International Telecommunications Union, https://www.itu.int/en/about/Pages/whatwedo.aspx.

[87] ITU-R lists all current study groups in operation, ITU-T those for study period 2017-2020, and ITU-D those for study period 2018-2021.

[88] This, and all data on ITU study groups, comes from: "ITU-T Study Groups, International Telecommunications Union, https://www.itu.int/en/ITU-T/studygroups/2017-2020/Pages/default.aspx; "Radiocommunication Study Groups," International Telecommunications Union, https://www.itu.int/en/ITU-R/study-groups/Pages/default.aspx; "ITU-D Study Groups 1 and 2," International Telecommunications Union, https://www.itu.int/net4/ITU-D/CDS/sg/index.asp?lg=1&sp=2018.

[89] "Members," International Telecommunications Union, https://www.itu.int/en/myitu/Membership/ITU-Members.

[90] This, and all other ITU member data, comes from Members," International Telecommunications Union, https://www.itu.int/en/myitu/Membership/ITU-Members.

Figure 19: ITU Members by Country Affiliation and Type[91]

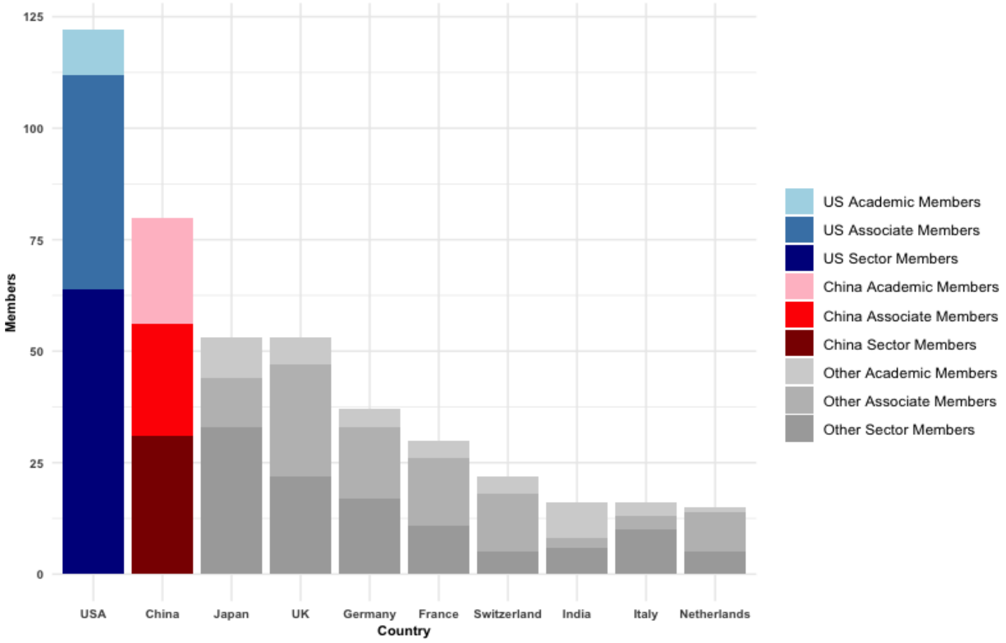
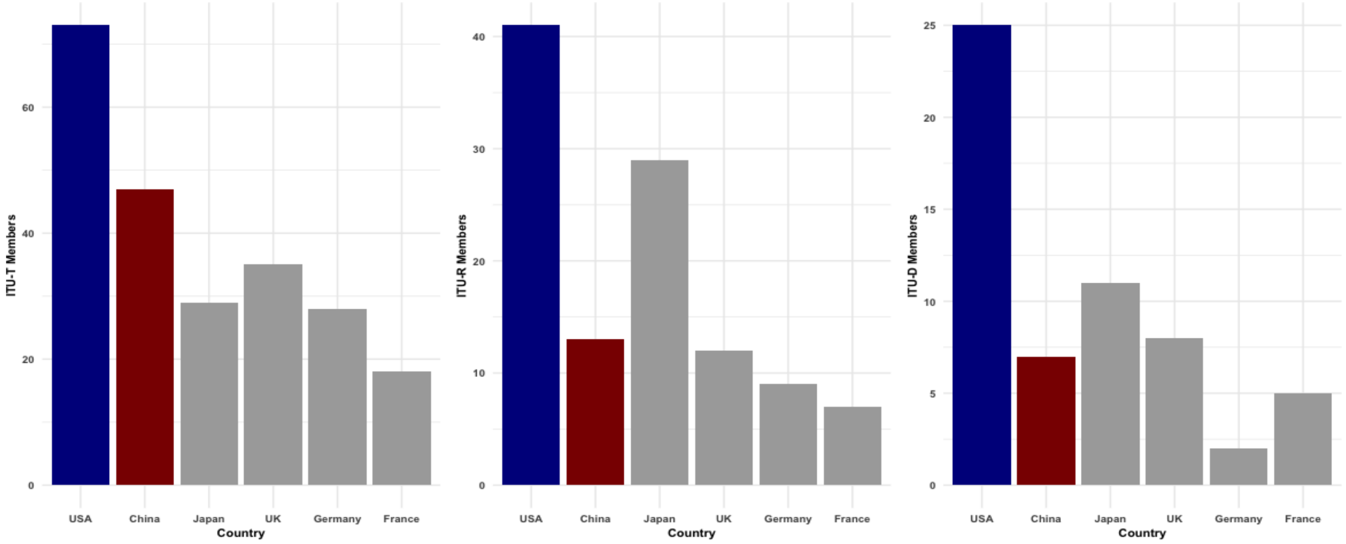


Figure 20: ITU Members by Sector and Country Affiliation[92]



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[91] This chart only includes the ten countries with the greatest number of total members. It does not differentiate among sector or associate members that participate in multiple ITU sectors: For example, one entity might have membership in both ITU-D and ITU-R, while another might not. This analysis would treat both entities the same way, counting each only once.

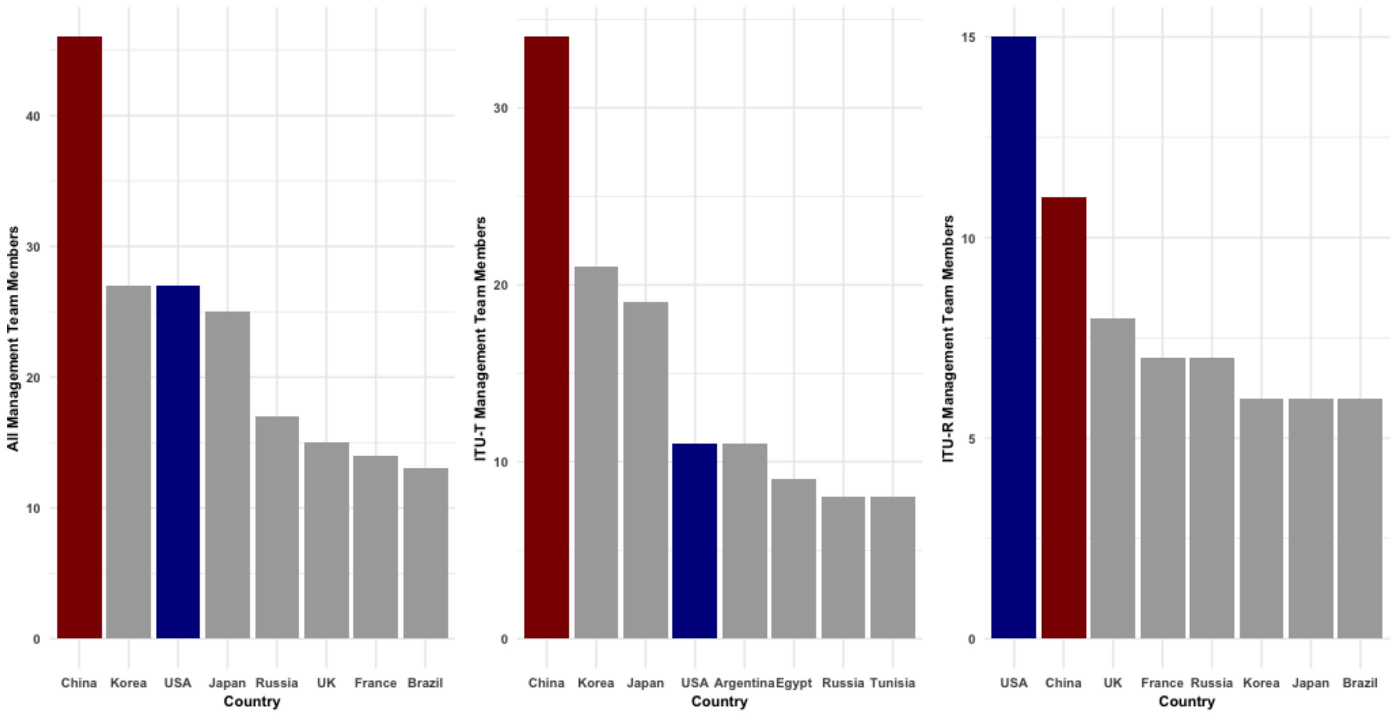
[92] This chart only includes the six countries with the greatest number of total ITU members. Those entities that are members of multiple sectors (e.g., both ITU-D and ITU-R) are counted in both graphs.

ITU Leadership

The nature of relative presence in, and corresponding influence over, the ITU changes dramatically if one looks not simply at members, but rather at leadership positions held. Every ITU-R and ITU-T study or focus group has a chairman and at least one vice-chairman. So do their subordinate work programs. These chairmen and vice chairmen of study groups, focus groups, and work programs are collectively known as "management teams." While the US boasts significantly more ITU members than does China, China far outranks the US – and every other country -- in terms of management team positions in ITU-R and ITU-T.

Of the 369 total management team positions across ITU-R and ITU-T, China holds 45, compared to 26 for the United States. That lead stems from China's presence in ITU-T, where China holds 34 out of 225 positions and the US only 11. By contrast, in ITU-R, the US holds more management team positions that does China, if by a smaller margin: 15 to 11, out of 144 total.

Figure 21: ITU-T and ITU-R Management Team Members by Country and Sector[93]



China has a particular lead, and this applies across both ITU-R and ITU-T, over the US, and all other ITU members, in study and focus group leadership positions – excluding their subordinate working programs from the analysis. China holds five study and focus group chair positions in total and 22 vice chairs, compared to four and six for the US, respectively. Six of China's seats are in ITU-R, compared to three for the US – despite the US lead over China in total ITU-R management team positions.

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[93] This chart does not include steering committee and task group leadership figures (though those would not change the overall standings). It looks only at the countries with the greatest number of management team members overall, in ITU-T, and in ITU-R.

Figure 22: ITU-T and ITU-R Study and Focus Group Chair and Vice Chair Positions, by Country[94]

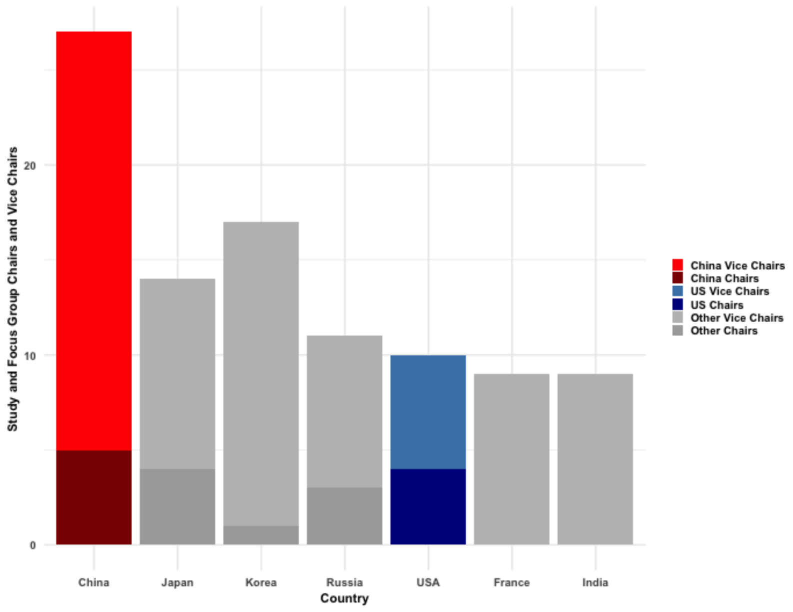
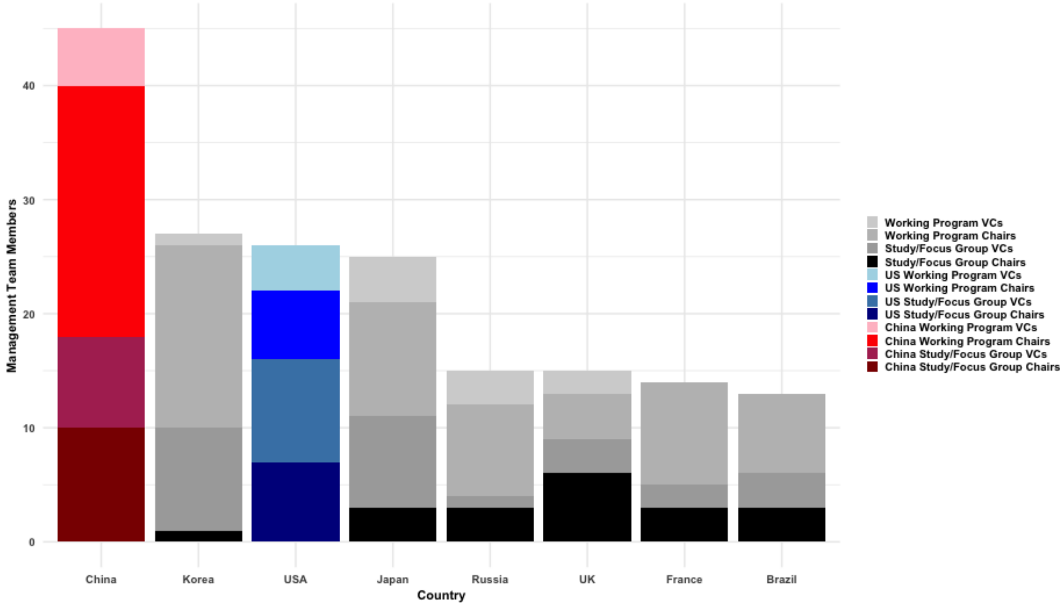


Figure 32: ITU Management Team Members by Country and Type[95]



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[94] This chart looks only at the seven countries with the greatest number of study and focus group chairs and vice chairs.

[95] This chart only includes those countries with the greatest number of total management team members. Working Program Chairs or Vice Chairs that also hold Study Group leadership positions are only counted in their Study Group capacities (e.g., an individual who is vice chair of a study group and chair of a subordinate working program is included in the count of study group vice chairs but not double counted as a working program chair).

Table 10: US, China, and Total Management Team Members by Type

Country	Study Group Chairs	Study Group Vice Chairs	Focus Group Chairs	Focus Group Vice Chairs	Working Program Chairs	Working Program Vice Chairs	Management Team Members
China	2	16	3	6	8	10	45
USA	2	5	2	1	9	7	26
Total	18	188	9	30	59	65	369

China's lead in ITU leadership does not only hold in numbers. It also holds in the scope of presence. Six of ITU-T's eleven study groups have no US leadership, either of the group itself or of its subordinate work program. Only one lacks Chinese management (SG3: Economic and policy issues, which is also without a US management team member). A similar dynamic holds in focus groups: Of the ITU-T's seven focus groups, the US is represented in the management team for only three of them – China for six. In ITU-R, China holds a management position, whether chair or vice chair, in all six study groups, while the US holds a post in only three (not including subordinate working program leadership).

The ITU-R cases point to an additional asymmetry – one of centralization -- between US and Chinese representation in the ITU: Every Chinese ITU-R study group leader is affiliated with a government or government-owned entity (e.g., the Ministry of Industry and Information Technology, National Radio and Television Administration). This reflects a broader dynamic. China's ITU members, and especially management team members, are overwhelmingly government-tied. Of China's 80 ITU-R, ITU-T, and ITU-D members, 49 are affiliated with government or government-owned entities,[96] compared to three of the 121 US members. And only nine of China's 45 management team members represent private entities, where 17 of the US's 26 do.

The centralization of Chinese representatives in the ITU parallels the satellite story: While the US may have greater representation at the ITU than does China, the US delegation is fragmented, responsive to private interests. China's is largely consolidated under government control. This may grant Beijing outsize influence in the ITU: If the bulk of China's ITU members, and especially members holding management positions, answer ultimately to the Chinese government, they can be coordinated in their approach to standards-writing, -recommending, and -voting. They can be operated as a bloc, pushing the Chinese government's strategic vision.

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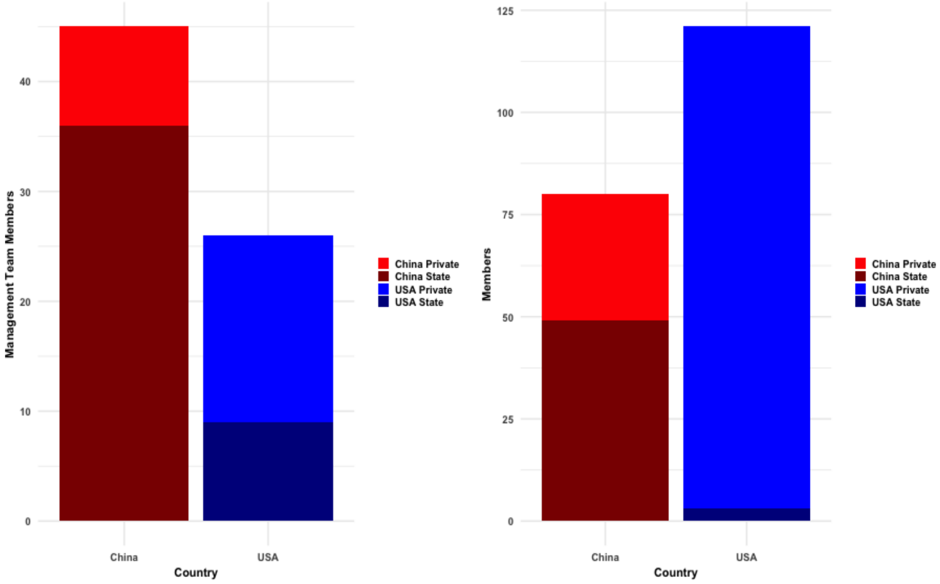
[95] This chart only includes those countries with the greatest number of total management team members. Working Program Chairs or Vice Chairs that also hold Study Group leadership positions are only counted in their Study Group capacities (e.g., an individual who is vice chair of a study group and chair of a subordinate working program is included in the count of study group vice chairs but not double counted as a working program chair).

[96] Not including State-invested companies, but including State-owned companies, universities, and research institutions, as well as government branches.

Figure 24: US and Chinese Management Team and Sector Members, by Government Affiliation



To put a finer point on this asymmetry – and the fragmentation, or disparate interests, of US ITU representatives compared to their Chinese counterparts -- the work program chair for ITU-T's Study Group 15 (Transport, access, and home) is classified as a US representative. However, his affiliation is with Futurewei Technologies US R&D Center, Huawei's Illinois-based research and development center. None of the ITU members classified as Chinese is affiliated with a foreign-owned entity.

Conclusion

This report seeks to provide baseline metrics and frameworks to support assessment of relative US and Chinese S&T capacity, strengths, and weaknesses across fundamental, synthetic, and downstream domains. It finds that while the US might benefit from a legacy advantage, China's centralization – and the ability to develop capital intensive infrastructures as well as to leverage private and public sector actors it bestows – may undermine that enduring US advantage. Modern technological trends may also raise the significance of synthetic and downstream, at the expense of fundamental, building blocks. This is critical because the US relative advantages are greatest in the latter domain.

Appendix

Table A: ISO Technical Committees of which ANSI Is the Secretariat

Reference	Name	Published standards	Standards under development
ISO/IEC JTC 1	Information technology	3293	557
ISO/TC 11	Boilers and pressure vessels [STANDBY]	2	0
ISO/TC 20	Aircraft and space vehicles	692	111
ISO/TC 31	Tires, rims and valves	78	20
ISO/TC 36	Cinematography	114	8
ISO/TC 42	Photography	207	21
ISO/TC 60	Gears	61	8
ISO/TC 68	Financial services	63	27
ISO/TC 69	Applications of statistical methods	118	23
ISO/TC 86	Refrigeration and air-conditioning	47	14
ISO/TC 104	Freight containers	40	5
ISO/TC 108	Mechanical vibration, shock and condition monitoring	192	26
ISO/TC 121	Anesthetic and respiratory equipment	102	46
ISO/TC 127	Earth-moving machinery	174	17
ISO/TC 131	Fluid power systems	237	30
ISO/TC 185	Safety devices for protection against excessive pressure	12	2
ISO/TC 189	Ceramic tile	29	9
ISO/TC 192	Gas turbines	18	3
ISO/TC 198	Sterilization of health care products	60	18
ISO/TC 204	Intelligent transport systems	302	87
ISO/TC 205	Building environment design	36	10
ISO/TC 209	Cleanrooms and associated controlled environments	18	5
ISO/TC 210	Quality management and corresponding general aspects for medical devices	32	4
ISO/TC 212	Clinical laboratory testing and in vitro diagnostic test systems	44	17
ISO/TC 214	Elevating work platforms	9	2
ISO/TC 215	Health informatics	210	62
ISO/TC 258	Project, programme and portfolio management	8	3
ISO/TC 260	Human resource management	24	8
ISO/TC 301	Energy management and energy savings	20	4
ISO/TC 304	Healthcare organization management	2	8
ISO/TC 327	Natural stones	0	0

Table B: ISO Technical Committees Led by SAC

Reference	Name	Published standards	Standards under development
ISO/TC 1	Screw threads	27	1
ISO/TC 5	Ferrous metal pipes and metallic fittings	59	11
ISO/TC 8	Ships and marine technology	383	102
ISO/TC 26	Copper and copper alloys	27	0
ISO/TC 41	Pulleys and belts (including veebelts)	77	4
ISO/TC 52	Light gauge metal containers	9	3
ISO/TC 61	Plastics	709	101
ISO/TC 70	Internal combustion engines	73	14
ISO/TC 96	Cranes	108	9
ISO/TC 105	Steel wire ropes	22	4
ISO/TC 130	Graphic technology	110	21
ISO/TC 132	Ferroalloys	69	2
ISO/TC 154	Processes, data elements and documents in commerce, industry and administration	33	10
ISO/TC 156	Corrosion of metals and alloys	100	31
ISO/TC 186	Cutlery and table and decorative metal hollow-ware	10	2
ISO/TC 195	Building construction machinery and equipment	37	11
ISO/TC 202	Microbeam analysis	26	10
ISO/TC 249	Traditional Chinese medicine	70	31
ISO/TC 255	Biogas	3	3
ISO/TC 263	Coalbed methane (CBM)	2	2
ISO/TC 264	Fireworks	21	2
ISO/TC 266	Biomimetics	4	2
ISO/TC 282	Water reuse	29	9
ISO/TC 289	Brand evaluation	2	3
ISO/TC 293	Feed machinery	0	3
ISO/TC 295	Audit data services	1	3
ISO/TC 296	Bamboo and rattan	6	5
ISO/TC 298	Rare earth	6	7
ISO/TC 306	Foundry machinery	2	6
ISO/TC 319	Karst	0	0
ISO/TC 321	Transaction assurance in E-commerce	0	2