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5G GEOTECHNOLOGICAL COMPETITION IN THE DIGITAL AGE

GLOBAL BENCHMARKS AND INSIGHTS FOR THE U.S.

CONSULTING | ANALYTICS | DIGITAL SOLUTIONS | ENGINEERING | CYBER

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EXECUTIVE SUMMARY

Technological innovation can tilt the global balance of power. Developing and incorporating innovative technologies grow economies, bolster militaries, and increase countries' reputation and influence. Consequently, countries that quickly employed new technology have historically gained power; those that lagged did not. To maintain global leadership through the 2020s, the U.S. must be a technology leader.

The first nations to enable, develop, deploy, adopt, and employ fifth-generation mobile network technology (5G) will significantly enhance their economies, militaries, and societies relative to other countries. 5G is part of a constellation of associated technologies that promise to empower commercial industries of the future, and transform defense, intelligence, and civilian government agencies. It will also connect physical and digital infrastructures at an unprecedented scale. In doing so, 5G will give countries new ways to project power through governance and diplomacy, foreign aid and trade, and security and law enforcement. At the same time, slow or poorly managed rollouts of these novel technologies can introduce new vulnerabilities to national and homeland security, constrain economic growth, and limit international influence.

Booz Allen created the 5G Power Framework to help national policymakers think holistically about how to securely harness this critical emerging technology. The framework evaluates coutnries' abilities to reap the maximum benefits of the 5G era. It uses publicly available qualitative and quantitative evidence to explore the extent to which countries have 14 key capabilities needed to enable, develop, deploy, adopt, and employ 5G. This evidence supports numeric scores, allowing us to precisely compare each country's ability to use 5G to boost its national power.

We applied this framework to 10 diverse countries to see where the race to 5G stands and identify best practices, benchmarks, and lessons learned to fuel American power and competitiveness. Presently, China and the United States (U.S.) are clear leaders in the race to 5G maturity, owing to their strengths in different areas. Our research indicates that the U.S. or China (but probably not any other countries) can still win this race.

TO SUCCESSFULLY ROLL OUT AND LEVERAGE 5G, THE U.S. STRATEGY SHOULD TARGET CAPABILITIES ACROSS THE FIVE LAYERS OF BOOZ ALLEN'S 5G POWER FRAMEWORK.

Strengthen the Foundation (Enable): The U.S.'s piecemeal, underfunded plans for 5G rollout should be realigned or replaced with comprehensive and coherent national strategies tied to substantial investments. Strengthening the National Technological Industrial Base (NTIB) requires coordinated policies and investments in research and development (R&D) and human capital. To address the skilled labor shortage, policies should target attracting and educating new workers, especially with increased R&D spending, and retaining those who drop out due to gender or visa issues. Key investments should scale R&D programs across the federal government, in partnership with the private sector and academia, to identify new practical use cases for 5G.

Develop National Industry (Develop): The U.S. cannot adequately build and secure the national 5G ecosystem. The U.S. must increase its ability to produce 5G hardware, software, and services domestically. Policies should target advanced capability and capacity to manufacture 5G hardware and software, and services to develop 5G architecture and assemble component parts. Developing a national industry to build and secure 5G will limit U.S. and partner nation (PN) dependence on global supply chains.

Ensure a Secure and Resilient 5G Infrastructure (Deploy): The U.S.'s preferred metrics for tracking the state of mobile communications deployment are inadequate for 5G, impeding targeted, data-driven policy. To understand the true density of the 5G ecosystem, the U.S. must collect additional metrics that reflect the rise of machine-to-machine connections in both public and private infrastructure. The U.S. should also open and make available spectrum for private use to expedite deployment. Increased funding for deployments in government installations and rural broadband initiatives will expedite market adoption and shrink the digital divide limiting professional opportunities and access to services for many Americans outside metropolitan areas.

Accelerate Adoption and Promote New Business Models (Adopt): The U.S. must achieve rapid market adoption of 5G to spark innovation in associated technologies and services and avoid perceptions of wasted spending on 5G's expensive infrastructure investment. The Federal Government should partner with state, local, tribal, and territorial governments (SLTTs) to the benefit of 5G. Public-private partnerships (PPP), as well as transnational initiatives (e.g., with North Atlantic Treaty Organization militaries), would further foster adoption by the U.S. and its partners.

Retake Global Technology Leadership (Employ): The U.S. should expand recent efforts to make non-Chinese 5G technology more cost-effective and readily available to countries early in the development and deployment phases of their 5G rollouts. China's early success in promoting its global 5G vision and technology rests largely on its effective use of foreign policy "carrots" that the U.S. has infrequently employed. The U.S. can use trade deals and direct development aid to counter China's offers to developing countries of directly subsidized 5G infrastructure. The U.S should also re-commit to aggressively pursuing leadership of international standards development organizations to ensure that 5G norms and policies better reflect U.S. values and national security priorities.

CONTEXT

THE IMPACT OF TECHNOLOGY ON GEOPOLITICAL COMPETITION

Advances in information and communications technology (ICT) have profoundly shaped national power and influenced global power dynamics for decades. An example of a country's use of technology to grow global power is Japan. It started when post-WWII Japan revitalized its economy and repaired its global reputation in part by becoming a world leader in electronics manufacturing. In just one decade, Japan used a combination of ambitious policies, strong foundations in human capital and R&D, and innovative domestic manufacturing capabilities to become a leading producer of transistors and semiconductors, critical components of computers, and electronics. What followed was an information revolution that arose from the development and maturation of digital computers, the internet, and information systems. These technologies enabled rich, instant global communications, collection, and computation of large amounts of data, and novel connections between people and machines. Countries that have led development, adoption, and implementation of ICT, like the U.S., and more recently, South Korea, Taiwan, and China, have seen their power and influence expand. Now, the questions are: in the era of 5G, the Internet of Things (IoT), and artificial intelligence, which country —or countries—will establish and maintain technological primacy? And how will they harness that primacy to achieve geostrategic outcomes?

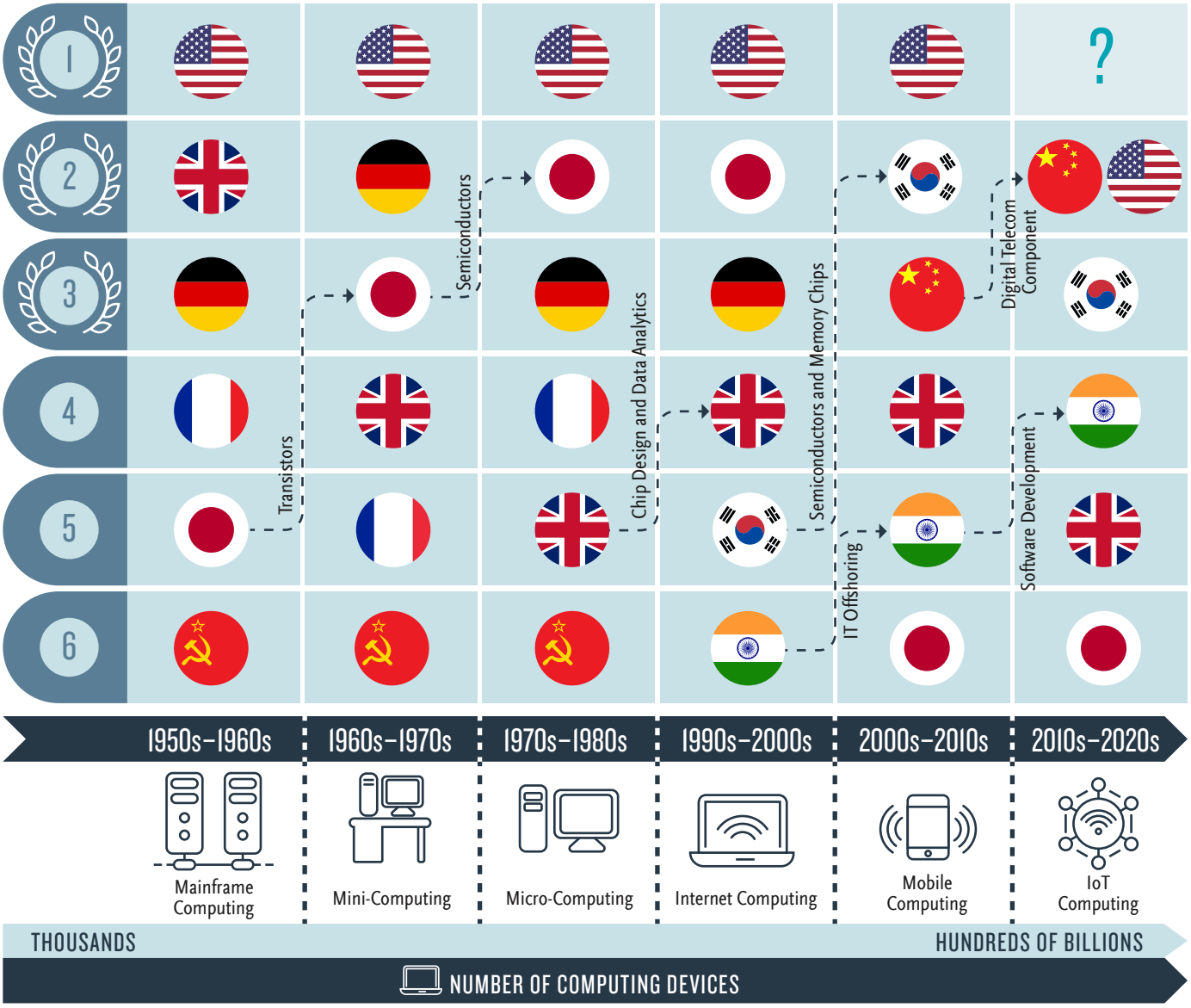


Figure 1 (from Booz Allen Analysis): Global Technology Leaders in Different Phases of the Information Age (1950–2030)

As information and communications technology (ICT) in the Digital Age reaches maturity, it will have greater impact on the global balance of power during the 2020s. Today, ICT will continue to enable traditional elements of national power. But as such technology becomes more pervasive and intertwined with government, business, and society, it will become a source of power in and of itself. Technological innovations will rapidly empower countries that can seize them. New IT hardware, software, and service businesses will enrich national economies. Digitized militaries will fight algorithmic wars at machine speed with extreme coordination, precision, and awareness. Soft power—diplomacy, trade, and aid—will increasingly correlate with a country's technology prowess and ability to export technology-centric value to allies, partners, and client states.

Winning the 5G race will enable a nation state to significantly enhance its economy, military, and society compared to other countries. 5G promises a significant step function transformation in speed, capacity, and reliability for mobile communications. Combined with artificial intelligence, quantum computing, and IoT devices, 5G will likely spur productivity gains, novel services, and other innovative technologies like robotic automation and self-driving cars. 5G's economic impact is widely estimated to be massive, adding $1.5 trillion to $2 trillion annually to the global gross domestic product (GDP).[1] In the U.S. alone, 5G is projected to add about 4.5 million new jobs.[2] It will also turbocharge military and intelligence operations, collecting and churning huge amounts of data into actionable insights. Countries leading innovative development and adoption will burnish their national profile, increasing their global cultural clout and attracting new investment and human capital generally.

For the U.S., winning demands a comprehensive national strategy and implementation plan tied to real funding and investments and meaningful collaboration between government and industry. Winning the 5G race means more than being the first to develop or deploy a 5G network. Rather, it requires having necessary national capabilities in place to enable, develop, deploy, adopt, and employ 5G technology. U.S. policymakers therefore need a holistic understanding of all levels of 5G maturation and need to continually recalibrate the balance of opportunities for technological innovation and adoption against the careful management of risks to national and homeland security to position the U.S. for success.

1 **McKinsey & Company** (2020), Connected World: An Evolution in Connectivity Beyond the 5G Revolution.
2 **CTIA** (2020), 5G Promises Massive Job and GDP Growth in the US.

5G GLOBAL BENCHMARK STUDY

To develop a national strategy for navigating future 5G challenges and opportunities, it is necessary to first understand where the global 5G race stands. Headline indicators and a pervasive focus on narrow, isolated metrics of rollout success have tended to paint the race's outcome as a foregone conclusion. A holistic consideration of the entire 5G race instead is necessary for an accurate appraisal, both of the race as it stands and of its future trajectory. Based on this framework, China and the U.S. are ahead, but the race is still early—and the likely winner is unclear.

5G POWER FRAMEWORK

The Booz Allen 5G Power Framework, shown in Figure 2, helps national policymakers think holistically about how to activate and harness 5G technology. The framework considers 5G's development as multi-layered, spanning the fundamental groundwork for creating 5G ecosystem technologies through development, deployment, adoption, and the strategic employment of 5G to grow national power. The framework is depicted in a linear fashion, but we would expect implementation to be iterative with feedback loops and continuous improvement between phases as necessary. We have identified 14 key capabilities any country must possess to succeed across the 5G's five layers of maturity. Each layer and capability was given a numerical score based on technical maturity and aggregated to form insights. Taken as a whole, the framework offers a comprehensive and repeatable way to assess readiness of a country to use 5G to gain geopolitical power, giving U.S. leaders insight into other countries to help shape policies and plans.

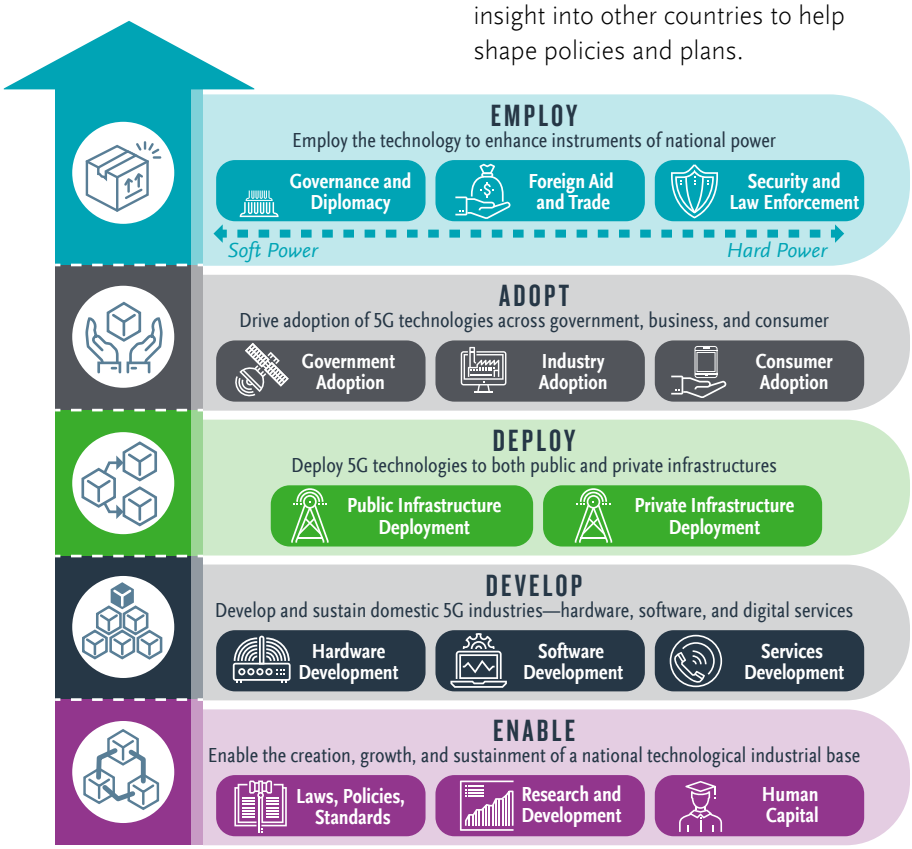


Figure 2: 5G Power Framework

RESEARCH METHODOLOGY

We applied this framework to 10 countries to discern best practices, benchmarks, and lessons learned for improving American competitiveness and power. First, we chose 10 diverse countries with geographic diversity, varied levels of 5G rollout, varieties of political and economic systems, and a mix of U.S. partners, allies, and competitors. Then, we gathered qualitative and quantitative evidence that the countries possess each of the 14 relevant national capabilities. Finally, we applied the rubric in Figure 3 to generate scores for each capability and layer of the framework (Figure 4). We used these scores to draw our conclusions.

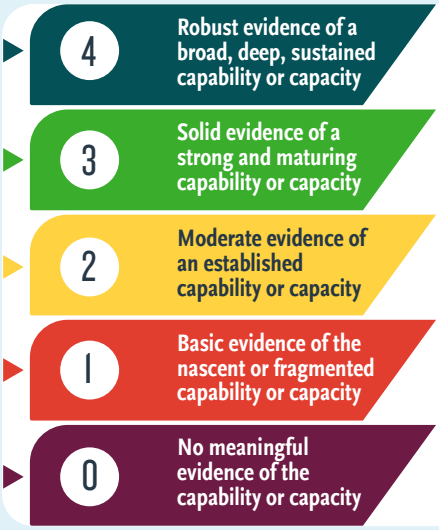


Figure 3: Scoring Criteria

OVERVIEW OF FINDINGS & RECOMMENDATIONS

No country has a mature 5G ecosystem that is fully developed, deployed, and adopted. Systemic fundamental challenges have impeded any country from achieving full 5G maturity. First, 5G will be powered by software-defined technologies, and no country currently produces enough skilled software and radio network engineering expertise to build and secure a national 5G ecosystem. Second, current 5G R&D investments are insufficient in scope and scale to identify practical applications for 5G. Without them, countries face a hollow infrastructure problem: widespread 5G deployments are wasted investments if government, business, and society see little value in adopting the technology. Finally, no country can design or build the entire 5G ecosystem domestically, adding supply chain risks to all 5G rollouts.

China and the U.S. are clear leaders in the race to build and secure 5G. Different successes and strengths suggest either country (but probably not any others) could win the race at this stage. China's successes include a national 5G strategy and coordinated, fully funded R&D programs. Two telecommunications companies are deploying 5G networks in China. Reports estimate 181 infrastructure deployments[3] and between 300,000 to 800,000 base stations provide limited nationwide coverage.[4] China's foreign aid and trade incentives of up to 80% discounts encourage the purchase of Chinese-made 5G equipment. Its increased involvement in international organizations aims to influence internet connectivity and facial recognition standards to support its national interests. Strengths of the U.S. include world class national human capital education and training pathways, and strong 5G technology development.

Figure 4: Country Scoring

There is a path to victory for the U.S. — it requires government, industry, and civil society to work together to reap the maximum benefits of 5G.

Comprehensive and coherent national strategies, plans, investments provide clear direction, and establishing and maintaining a strong national technology and industrial base (NTIB) produces a skilled workforce, creates domestic manufacturing capacity, and limits dependence on global supply chains. Fostering public-private infrastructure partnerships combine diverse perspectives, authorities, and capabilities.

Widespread adoption across government, business, and society stabilizes long-term economic growth by operationalizing the deployed infrastructure, bringing the ecosystem of data-connected devices to life. Only then are countries best positioned to employ 5G for national applications to exert influence across a spectrum of hard and soft power that spans security and law enforcement, foreign aid and trade, and governance and diplomacy. Additionally, sustained diplomatic engagement with partner nations are opportunities to set and shape the 5G agenda in a direction that advances U.S. interests, and promote security cooperation to address shared threats and derive mutual benefits.

3 **Ookla** (2021), Ookla 5G Map—Tracking 5G Network Rollouts Around the World.
4 **RCR Wireless News** (2020), Chinese Carriers to Deploy 600,000 5G Base Stations in 2021: Report.

5G GLOBAL BENCHMARK STUDY

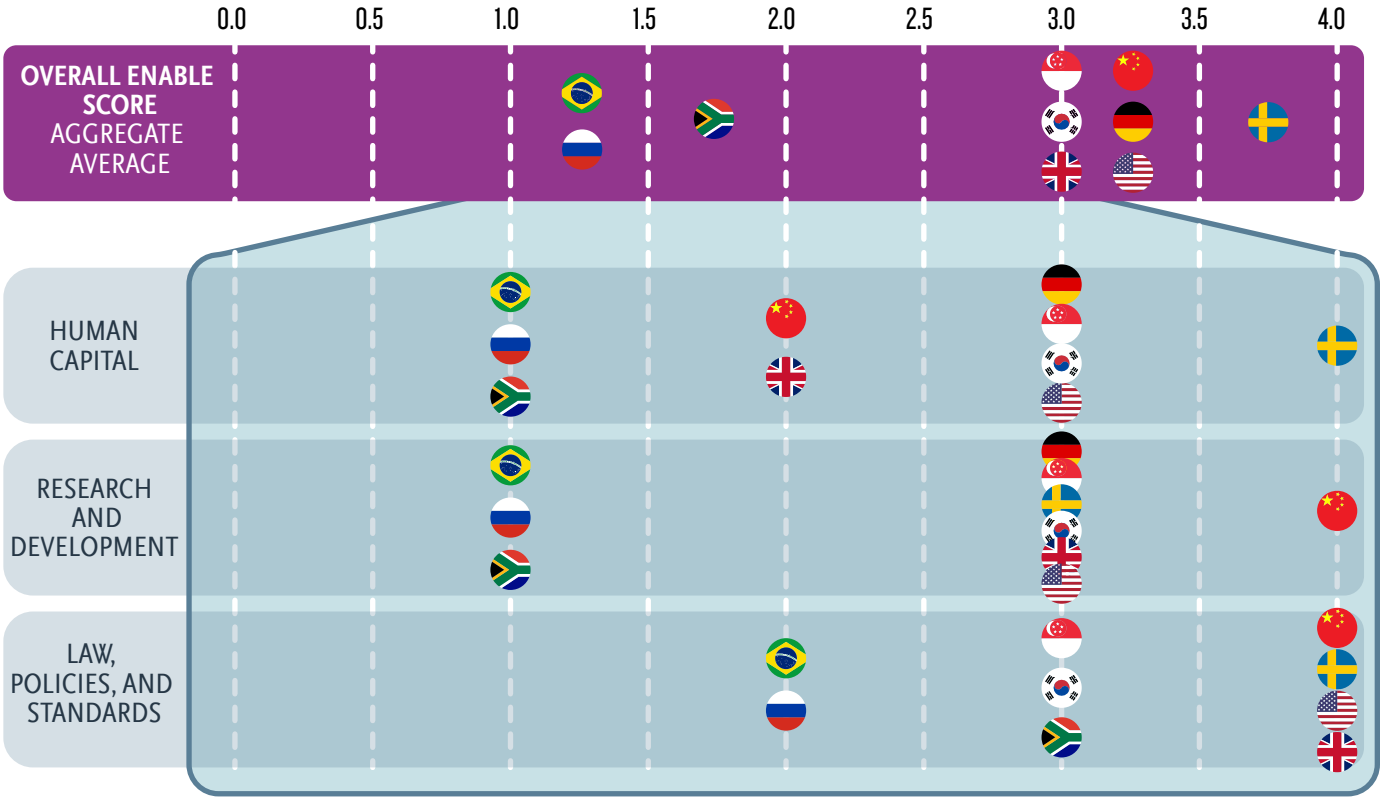


Figure 5: Enable Layer Scorecard

Enable

Laws, policies and standards, R&D, and human capital programs are the foundations of technological advancement. Cohesive, comprehensive foundational laws, policies, and standards, and simultaneous investments in human capital and R&D enable countries to create and sustain a robust NTIB.[5] Countries that build and innovate local skilled software workforces, properly fund R&D for 5G technology ecosystems and industries, and ensure secure and resilient software-based critical infrastructure will have stronger NTIBs and are likely to outperform others on a global scale.

Many countries have relevant laws, policies, and standards. China has the largest workforce, while the U.S. has the most highly skilled workers. China outspends the rest of the world by almost 3x on R&D.[6]

We recommend the U.S. strengthen its foundational capabilities. Two key policy initiatives can help to pull the U.S. ahead. First, fund and scale 5G R&D pilots across the Federal Government, modeled after the Department of Defense's $600 Million 5G Experimentation and Testing program.[7] Second, foster public-private partnerships to encourage experimentation and adoption in the commercial sector to power the industries of the future; public-private partnerships should leverage the work with the Department of Commerce to better integrate 5G technologies into diverse U.S. industries.

[5] Established by 10 U.S.C. §2500 to support U.S. national security objectives, the NTIB consists of the people and organizations engaged in national security and dual-use R&D, production, maintenance, and related activities within the United States, Canada, the United Kingdom, and Australia.
Congressional Research Service (2021), Defense Primer: The National Technology and Industrial Base.

[6] Internal Booz Allen Analysis.

[7] **Department of Defense** (2020), DoD Announces $600 Million for 5G Experimentation and Testing at Five Installations.

BENCHMARKING FINDINGS AND INSIGHTS

Most countries have national laws, policies, and standards related to 5G, but they range from highly streamlined to uncoordinated. The U.S., the UK, and China all have a strong suite of 5G laws, policies, and standards. Efficiency in implementing and enforcing these standards varies. China has developed a more cohesive legal and regulatory framework for building and operating 5G networks than most other surveyed countries. This legal and regulatory centralization provides clarity and enables China's government and businesses to operate more efficiently, developing robust strategies and implementing them relatively quickly. Conversely, the U.S. and U.K. have a patchwork of laws and regulations that have developed over time since cybersecurity became an issue of concern in the 1990s—these sometimes overlapping authorities and stakeholders' equities can at times slow progress.

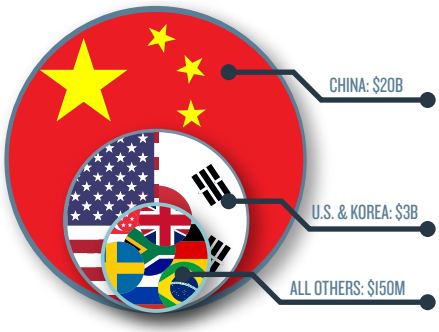


Figure 6: R&D Spending

China's 5G R&D investments are, by far, the largest and most coherent. China plans to spend $150B on 5G R&D by 2025.[8] In 2020, China's Huawei spent $20B on 5G R&D,[9] which is nearly three times more than the U.S. (Figure 6).[10] Strong top-down 5G laws and policies align China's R&D investments to strategic national-level priorities. In other countries, 5G R&D is underfunded and less coordinated. Of note in the U.S., the National Science Foundation is working with the Defense Advanced Research Projects Agency to create testbeds for wireless research to innovate beyond 5G and into 6G. The National Science Foundation has devoted $6.1M to Platforms for Advanced Wireless Research to allow academic and industry researchers to experiment with approaches at scale, partnering with leading domestic and foreign network vendors (i.e., Juniper and Ericsson), device manufacturers (i.e., Samsung and Qualcomm), and wireless carriers (i.e., AT&T and Verizon) to promote U.S. leadership in wireless technologies and cultivate a next-generation workforce. The size and scope of U.S. investment pales in comparison to China, but this is a positive development that will advance basic and applied 5G research for national defense priorities. Still, the disparity in the size and scope of 5G R&D investments should be deeply concerning for U.S. policymakers. Recall that the U.S. won the Cold War in large part by outspending the Soviet Union.

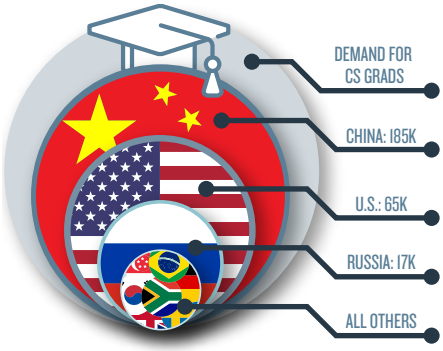


Figure 7: Number of Computer Science Graduates

No country produces and retains enough skilled software engineers to meet the demand. (Figure 7) No country has enough software engineers that reside domestically in the NTIB to develop, deploy, operate, and maintain a national 5G ecosystem. China has the largest workforce of around 774.7 million people,[11] but the quality of its national training and education programs lags other nations, holding it back from fully capitalizing on the size of its labor force. The U.S. has the most skilled computer science workforce, but labor shortages prevent it from fully capitalizing on its highly skilled knowledge base.[12] With the leading position globally, the U.S. currently has 4.2 million software engineers;[13] however, the Bureau of Labor Statistics indicates that by 2026, the shortage of engineers in the U.S. will exceed 1.2M. According to a report published by Boston Consulting Group in the U.S. "every 1% shortfall (about 30,000) in talent supply could mean missing out on $20B (1.5%) of the potential 5G benefits from 2020 to 2030."[14] This means that for every year the U.S. falls behind in human capital it is at a significant financial loss to the national, and global, GDP. The relative global gap in the computer science and engineering workforce is even wider (26 million currently, with a need for an additional 85.2 million by 2030).[15] The obvious opportunities presented by the global IT workforce deficit will likely compel many countries to develop programs that groom and upskill the next generation of talent, making it imperative that the U.S. act quickly.

All countries are failing to groom software security experts, instead focusing on software development. Human capital initiatives, limited as they are, focus almost entirely on grooming software designers, developers, and engineers.[16] Securing that software—in design, through development, and post-deployment—is less than an afterthought. Countries are missing half the equation: the need to also grow a domestic workforce that can proactively manage the new digital risks of a software-centric world. This is a systemic problem that will impact the development and deployment of 5G networks and the extended ecosystem of connected IoT devices that run on the backbone of 5G.

8 **RCR Wireless News** (2019), China to Invest Over $150 Billion in 5G Networks by 2025: Report.
9 **Sam Shead** (2021), China's spending on research and development hits a record $378 billion.
10 **Congressional Research Service** (2020), Federal Research and Development Funding: FY2021.
11 **Statista** (2019), Number of Employed People in China 2009–2019.
12 **Proceedings of the National Academy of Science of the United States of America** (2019), Computer Science Skills Across China, India, Russia, and the United States.
13 **DAXX** (2020), How Many Software Developers Are There in the World?
14 **BCG** (2021), 5G Promises Massive Job and GDP Growth in the U.S.
15 **DAXX** (2020), The Software Developer Shortage in the U.S. and the Global Tech Talent Shortage in 2021.
16 Internal Booz Allen Analysis.

U.S. POLICY RECOMMENDATIONS

Double 5G R&D budgets, and scale funded 5G R&D pilot programs across the U.S. Federal Government. Congress should increase its allotted funding to executive branch departments and agencies for 5G R&D programs to find effective use cases for 5G networks. Special attention should be given to programs related to the ecosystem of connected IoT devices that advance department and agency missions. Expanding pilot programs, such as the Platforms for Advanced Wireless Research program, across all departments would be a step in the right direction to close the gap between the U.S. and China's commitments to R&D. Additionally, the U.S. should look to leverage innovations from public-private partnerships with small businesses by increasing funding for the Small Business Innovation Research and Small Business Technology Transfer programs to encourage small businesses to engage in Federal R&D.[17] At the time of this writing, Congress was considering passing the Endless Frontier Act. This bipartisan legislation would provide $200 billion in funding for technology and related research. Most notably, it would provide $100 billion to the federal government's new science agency the National Science and Technology Foundation over the next five years to research key technologies such as artificial intelligence and machine learning, robotics, high performance computing, and other advanced technologies. Another $10 billion would be provided to the Department of Commerce to designate at least ten regional technology hubs for R&D and manufacturing of these key technologies. If passed, the Endless Frontier Act would be a major step in addressing China's push for technology leadership and global power.

Establish and fund a national lab and public-private partnership to create and manage voluntary security certification and labeling for 5G communications and IT products and services. As more devices are integrated into the national 5G ecosystem, mechanisms are needed to ensure those devices are secure and resilient. For example, Brazil's Telecommunications Research and Development Center's Certification Lab, which was launched in December 2020, has already begun to perform conformity assessment tests of 5G equipment, to guarantee quality, safety, interoperability, and radio spectrum protection for the country's 5G networks.[18] Notable examples in the U.S. are Underwriters Laboratories — the largest and most reputable independent, nonprofit testing laboratory in the world,[19] and National Institute of Science and Technology Baldrige Performance Excellence Program which involves government, industry, and academia to oversee the Presidential award for performance excellence.[20] Without transparent mechanisms to compare security between products, owners, and operators, consumers cannot easily price security into purchasing decisions. Issued certifications should be publicly accessible and manufacturers should be encouraged to display certification marks on product packaging. Vendors should then be required to build to open standards, 3rd Generation Partnership Project standards, and other applicable standards to ensure interoperability.

Attract and retain already trained members of the advanced software engineering workforce. In the short term, the U.S. should make it easier to attract and retain foreign computer science talent, especially those educated at U.S. universities. The National Science Foundation has noted that the U.S. increasingly struggled in the past 15 years to attract and retain science and engineering doctoral candidates, especially from China and India, pointing to visa difficulties and rapidly growing R&D investment by foreign governments.[21] Policies are needed to keep already trained female IT workers in the U.S. workforce, who drop out at a 45 percent higher rate than men.[22] Studies find that core problems include the gender pay gap, poor family-work balance, and pervasive anti-women bias in the IT sector.[23] Immediate solutions could emphasize specialized technical education programs to provide a focused infusion of knowledge in key technical 5G areas in shorter timeframes by side stepping traditional higher education pathways.

Educate and retrain the U.S. workforce for IT careers. In the long term, the U.S. can scale the supply of skilled workers by educating young people or reskill portions of the existing labor force. The U.S. should do both strategically—through national K–12 and higher education systems, government incentives for reskilling programs, and public-private education and training partnerships—to fully capitalize on a larger domestic knowledge base. Singapore offers a possible model for success. It has created a best-in-class program to integrate training in emerging technologies, coding, and computational thinking into primary education through the Singapore Cyber Youth Program in an effort to steer young citizens into careers in cybersecurity and software engineering.[24] The U.S. should implement similar education and reskilling programs with particular focus on rural communities, especially impoverished communities likely to experience continued economic downturn caused by the shift away from fossil fuels. Green initiative funding could be used for training and reskilling programs in areas affected by fossil fuel reduction. Government and industry partnerships can provide remote training to upskill workers in these areas.

17 **Small Business Innovation Research** (2020), About the Small Business Innovation Research and Small Business Technology Transfer Programs.
18 **GTI** (2020), Brazil 5G Certification Lab to Start Work in December.
19 **Underwriters Laboratories** (2021), About Us.
20 **NIST** (2021) How Baldrige Works.
21 **National Science Board** (2020), Foreign-Born Students and Workers in the U.S. Science and Engineering Enterprise.
22 **Kristen Lotze** (2019), How Tech Companies Can Recruit and Retain More Women, Tech Republic.
23 **Kristen Lotze** (2019), How Tech Companies Can Recruit and Retain More Women, Tech Republic.
24 **CAN** (2019), Coding Classes for Primary School Pupils to Be Rolled Out Next Year.

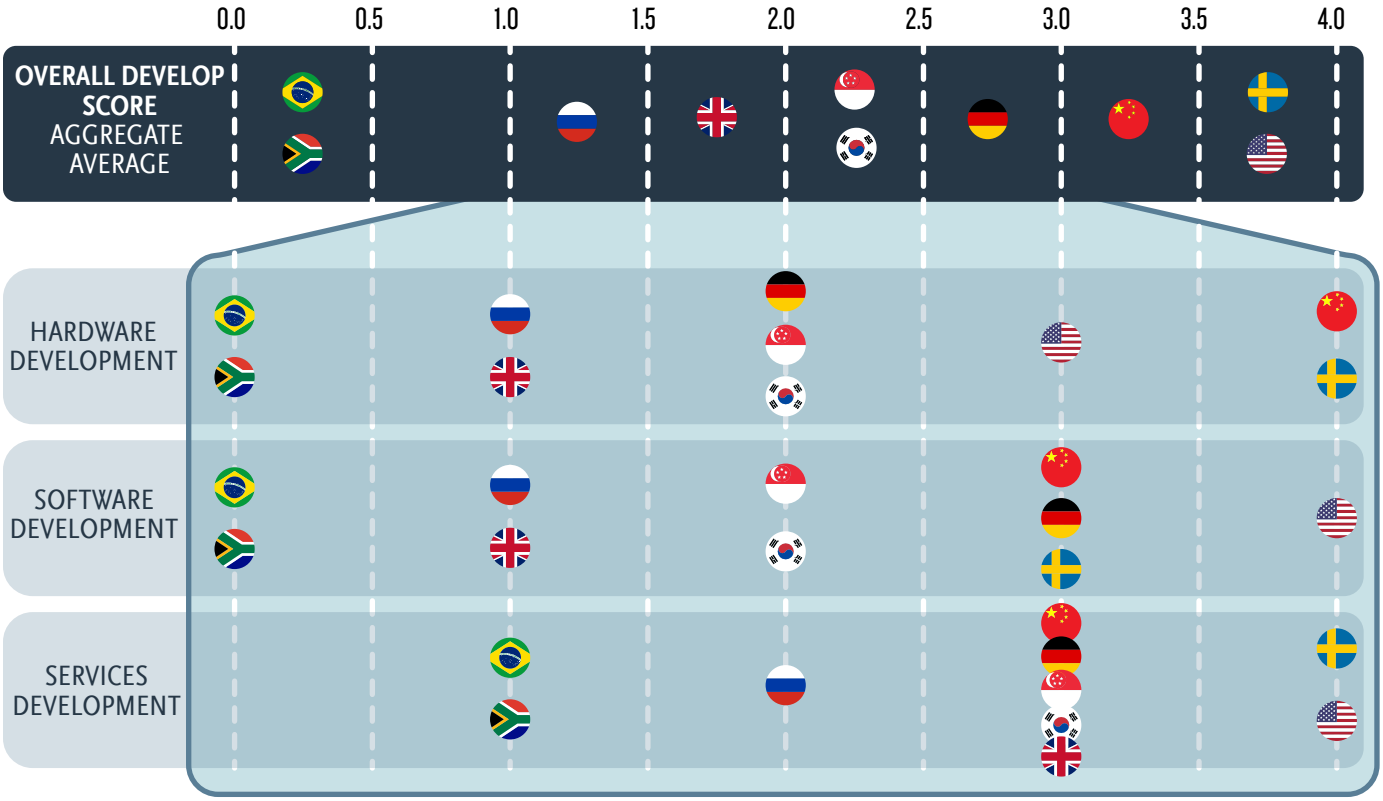


Figure 8: Develop Layer Scorecard

Develop

A national industry with capacity to develop 5G chips, hardware devices, software, and services domestically creates economic growth and reduces geostrategic risks stemming from an overreliance on foreign suppliers that creates supply chain vulnerabilities. National industries can also help mitigate risks stemming from reliance on untrusted hardware and software providers from abroad.

Research indicated that the U.S. and Sweden are leaders in this "Develop" layer (Figure 8). That said, in the near term, no country has manufacturing capacity to develop 5G hardware domestically at scale. In the long term, virtualized network functions will displace 5G hardware, which will increase demand for software development and compound existing labor shortages.

We recommend that the U.S. develop its national industry for 5G. It can do so by re-shoring the development of 5G hardware, software, and services to mitigate national security risks, and creating a world-class domestic software development industry through government grants and investments, public-private partnerships, and national standards and incentives.

BENCHMARKING FINDINGS AND INSIGHTS

Currently, no country can develop 5G hardware domestically on a national scale, which leaves all countries dependent on the global supply chain. (Figure 10) Many companies design 5G hardware, with Huawei, Qualcomm, Ericsson, and Intel leading the way in chip design, small cell antennas, and other equipment required to operationalize 5G, as shown in Figure 9.[25] These companies put the U.S., China, and (to a lesser extent) Sweden on the map as industry leaders in the design of 5G network component parts. But most companies outsource the manufacturing of these component parts to pure-play foundries in Taiwan and other parts of East Asia.[26] These offshore manufacturing practices increase risk created by hardware supply chain vulnerabilities, including the introduction of potentially malicious software and hardware, use of counterfeit components, and/or the impact of shoddy designs, disorganized manufacturing processes, and poor maintenance procedures.[27] Even if the manufacturers are strategic allies, the risk exposure is unnecessary if it can be avoided through domestic production.

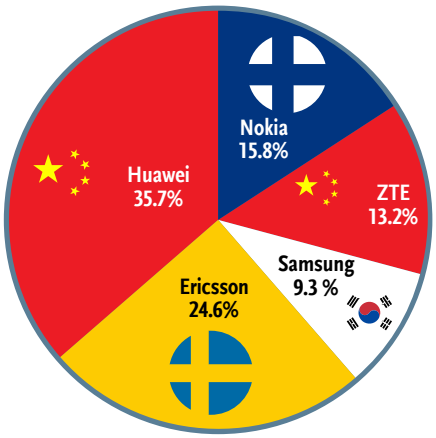


Figure 9: Market Share of Top 5G Hardware Companies Globally [25]

[25] **Phate Zhang, cnTechPost** (2020), Huawei, ZTE hold 48.9 percent share of 5G telecom equipment market.
[26] **Lori Ioannou, CNBC** (2020), A brewing U.S.-China tech cold war rattles the semiconductor industry.
[27] **CAN** (2019), Coding Classes for Primary School Pupils to Be Rolled Out Next Year.

Software-defined networks will eventually displace 5G hardware, which will increase demand for software development and multiply existing shortages of skilled software engineers. Recognition of the operational and security lenges associated with limited competition and choice in the hardware market is driving the demand for interoperable software-defined technologies. The market is split over whether to use proprietary or collaborative open-source solutions (like "Open RAN") to decouple hardware and software. Regardless, the demand for software-defined technologies—and a skilled workforce to build and secure them—will explode in the next several years as 5G networks are more widely deployed and adopted. The U.S. and Germany have expressed concern at their nation's inability to scale the NTIB, and meet this demand (Figure 11).

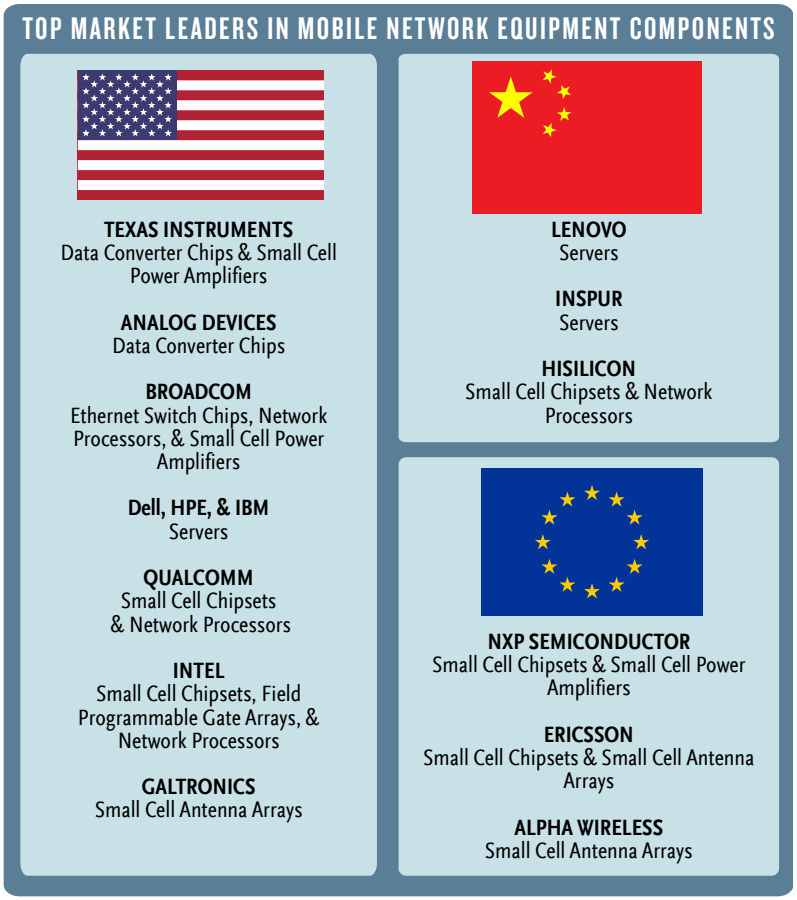


Figure 10: Market Leaders in 5G Component Parts[27]

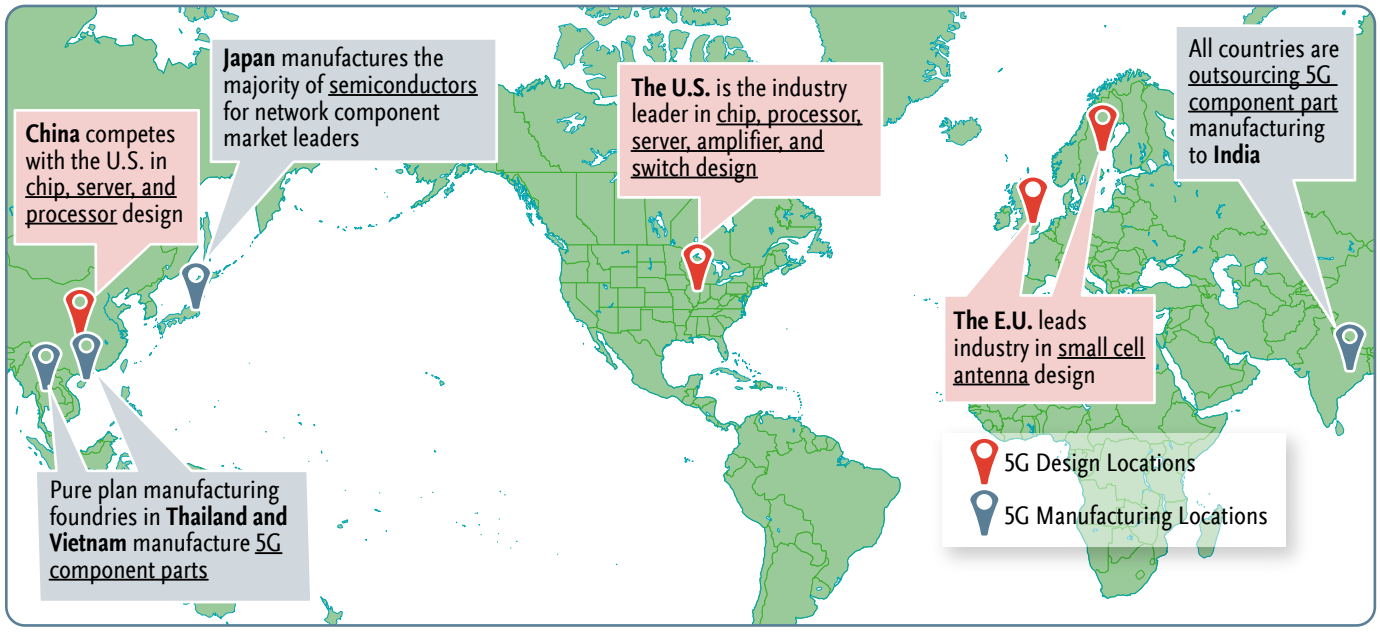


Figure 11: Disaggregation of Design and Manufacturing in the 5G Hardware Industry

[28] **CISA** (2019), 5G Wireless Networks: Market Penetration and Risk Factors.

U.S. POLICY RECOMMENDATIONS

Re-shore the development of 5G chip manufacturing, hardware, software, and services to mitigate national security risks posed by global supply chain vulnerabilities and intellectual property theft. No country has been able to successfully take this action, and in fact many countries have moved increasingly in the direction of offshoring. For example, South Korea formerly had a robust chip manufacturing operation, which it moved to China in the early 2000s, and more recently it has relocated factories to India because of rising geopolitical friction and overdependence on Chinese production.[29] Telecommunications companies have in recent years committed to adding skilled jobs to their American operations and ended several offshoring contracts with foreign governments. The Federal Government should continue to encourage and accelerate this practice through a mix of economic incentives. By collocating operators with original equipment manufacturers, chipset manufacturers, software developers, the U.S. can establish a domestic ecosystem that will drive economic growth. Additionally, countries that can develop national 5G ecosystems domestically are better positioned to manage supply chain vulnerabilities, protect corporate intellectual property, and create jobs.

Create a world-class domestic software development industry through government grants and investments, public-private partnerships, and national standards and incentives. Time is of the essence to build this domestic capability, as there is still opportunity to attain benefits from first-mover advantages. However, the real long-term economic value of a national 5G ecosystem is in software and the services delivered through software-defined networks. The U.S. has the skills in the NTIB to develop this software but lacks personnel in sufficient numbers. To that end, government grants and partnerships should focus on software, to accelerate innovation and competition in the market and help the winners scale. National standards and incentives ensure 5G hardware, software, and services are developed responsibly rather than prioritizing functionality over security in the race to be first to market.

The U.S. should continue to request funding for O-RAN R&D and for collaboration with international partners to build and secure 5G software and hardware solutions.

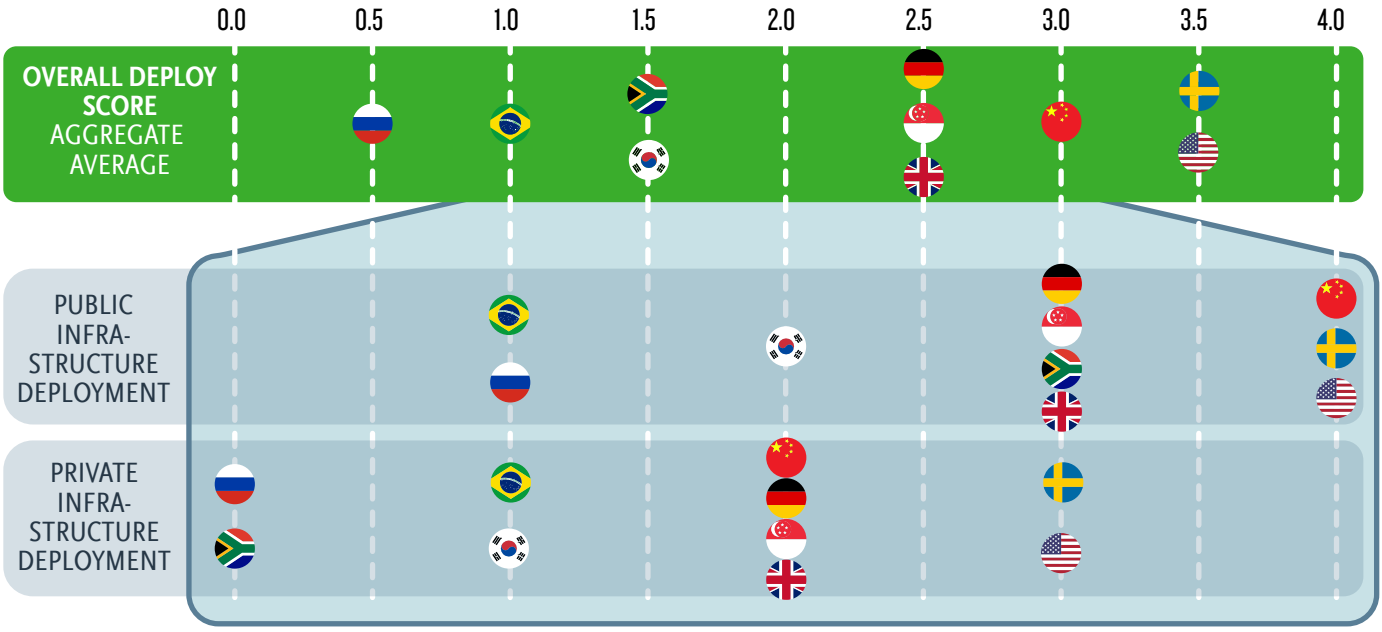


Figure 12: Deploy Layer Scorecard

Deploy

National 5G deployments need to be secure and resilient. 5G networks will run on a vast backbone of public and private infrastructure. Build-out times to deploy this infrastructure will be considerably longer than previous evolutions (i.e., 1G–4G). Deployments will retrofit existing 4G long-term evolution (LTE) base stations and introduce new small cell technology into the ecosystem. Doing so will greatly expand the network attack surface. As such, 5G deployments require collaborative efforts from the public and private sectors to ensure that national 5G infrastructures are "secure and resilient" by design.

Research indicated that public 5G infrastructure is partially deployed in most of the benchmarked countries, but hardware development shortages, hardware deployment bans, speed and coverage limitations, and competition among commercial providers impede full public deployments. Private infrastructure deployments exist but are much less common and promote innovation but create national security loopholes.

We recommend the U.S. update metrics to accurately measure the true extent of national 5G deployments, open and make available spectrum for private use, and continue to incentivize federal programs to create opportunities for future deployments in government installations and rural broadband initiatives.

BENCHMARKING FINDINGS AND INSIGHTS

Public 5G infrastructure is partially deployed in many countries. In the two leading nations, 5G is available in 341 cities in China, and 279 cities in the U.S.[30] Of the other benchmarked countries, Germany, Singapore, Sweden, South Korea, and the U.K. have deployed 5G networks. China's successful domestic deployments are due in large part to strategic national investments and intense competition between national service providers. Internationally, Chinese companies have already finalized more contracts to provide 5G hardware for national deployments than any other telecom company — half of which are for 5G networks in Europe, as well as the only 5G contract in Africa. China can attribute its international success to its strategy of providing inexpensive hardware to partner nations. China risks losing some of its international market share because of responses to policies and laws enacted by the U.S. and its allies banning the use of hardware from Chinese companies Huawei and ZTE in public infrastructure deployments. However, U.S. companies could potentially be excluded for decades in places where Chinese hardware is already deployed if the host nation chooses Huawei or ZTE to upgrade the existing infrastructure.[31] North America is projected to be ahead in conversion from legacy generations to 5G technology by 2026, but 5G service providers will require more government support to achieve the targeted 80% conversion rate in the next 5 years.[32] Russia is falling behind many of the other benchmarked nations, with public deployment only starting in 2020. It is projected to reach 46 million people by 2025, equivalent to 20% of connections.[33]

Hardware development shortages, hardware deployment bans, speed and coverage limitations, and competition in the communications sector impede full public deployments. The same challenges that plague development—human capital shortages, underfunded R&D, and limited choice and supply of hardware (stemming from limited

30 **Catherine Sbeglia** (2021), Comparing 5G progress in the U.S. and China.
31 **David Sacks** (2021), China's Huawei Is Winning the 5G Race. Here's What the United States Should Do To Respond. Council on Foreign Relations.
32 **Global System for Mobile Communications** (2019), The Mobile Economy: Russia & CIS 2019.
33 **Global System for Mobile Communications** (2019), The Mobile Economy: Russia & CIS 2019.

competition and compounded by hardware bans on untrusted vendors)—contribute to the lag in deployments. Chip shortages and spectrum allocation challenges limit existing 5G network speeds and coverage. Existing 5G network deployments in the U.S. are displacing legacy telecommunications services, setting up a corporate battle between 5G companies and 4G LTE providers as they compete for market share in the communications sector.

Private infrastructure deployments promote innovation but create national security loopholes. The market for private 5G networks globally is estimated at $1 billion, and an estimated 37% compounded annual growth could expand the market to almost $9 billion in the next five years.[34] Deployment of private 5G networks is lagging due to many of the same challenges facing public deployment; however, additional spectrum availability is helping facilitate the growth of private 5G networks. Isolated examples of private 5G deployment and innovation do exist: German aviation company Lufthansa deployed two distinct private networks to test business applications of 5G technology.[35] Widespread deployment of private 5G networks promises to drive real innovation and value but also presents security concerns. The U.K. banned all Huawei hardware from its public 5G infrastructure, but the Chinese company may still be able to establish a presence in the country through its recent partnership with Cambridge Wireless to build the first private 5G testbed in the U.K.[36]

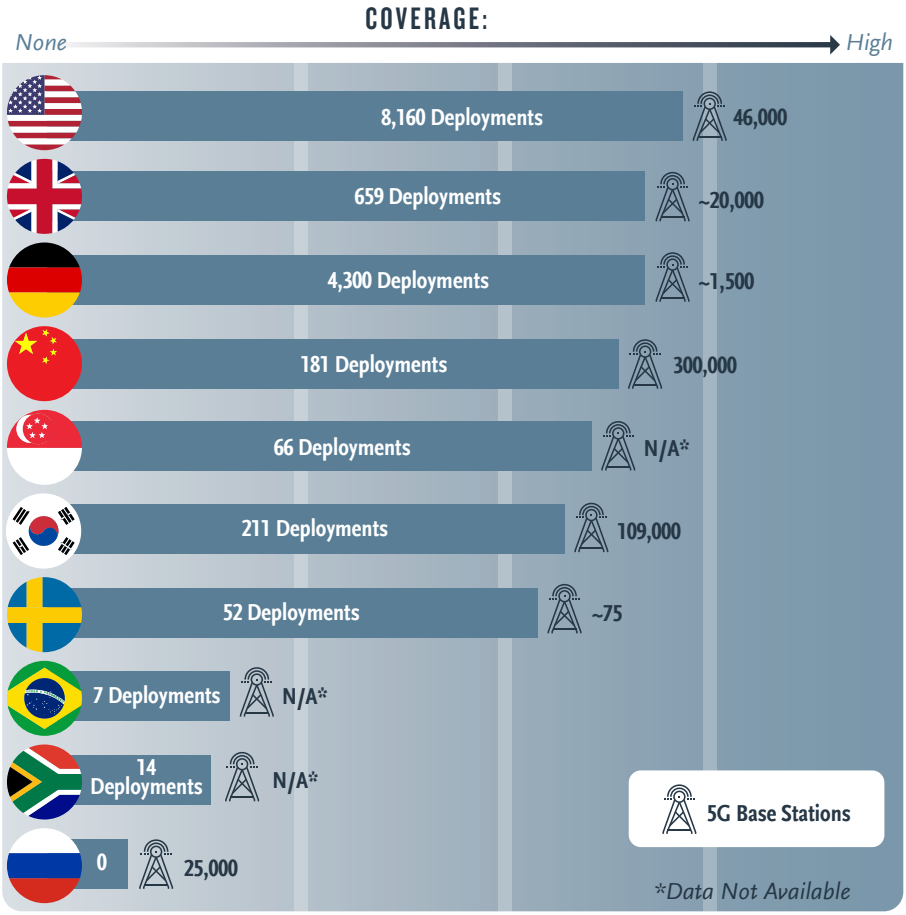


Figure 13: 5G Public Deployments and Coverage Chart and Number of Base Stations

U.S. POLICY RECOMMENDATIONS

Engage the Department of Commerce's National Telecommunications and Information Administration (NTIA), as well as industry leaders, to update metrics that accurately measure true 5G deployment. Previous deployments (1G–4G LTE) used the number of base stations to measure the size of the network infrastructure, which is not a very precise and accurate reflection of true deployment. To measure the size of the network infrastructure more accurately, the U.S. should capture metrics on the number of 5G small cells in addition to base stations. Traditional metrics used the number of mobile subscribers (i.e., people with a voice plan, which are underestimated) to measure the per capita density of the number of devices on the network. The reliance on mobile subscriber metrics being attributed to voice plans has been eclipsed by the fact that often people are likely to use data plans rather than voice calls. In a 5G ecosystem, the density of devices that touch the network will be exponentially greater, and therefore, metrics should also capture the total number of data-connected devices. Comprehensive metrics inform policy decisions and affect the calculated value of systems and how to best protect them. We recommend the NTIA partner with top telecommunications service providers in the U.S. to develop and measure progress against a more comprehensive set of metrics, to accurately understand the true status of national 5G deployments. Incomplete metrics could significantly under-value public and private infrastructure, thereby limiting funding for its development and deployment.

Continue to incentivize federal programs and create opportunities for SLTTs to have a central role in 5G development, deployment, and early adoption phases. Engaging SLTTs across 5G phases can empower national economic growth by expanding the coverage of 5G systems from urban to rural areas, and encouraging the reskilling of the local workforce

[34] **Polaris Market Research** (2020), Private 5G Network Market Size and Share.
[35] **Lufthansa Technik** (February 2020), Premiere for 5G Networks in Aircraft Maintenance.
[36] **Huawei** (November 2020), Cambridge Wireless and Huawei Partner to Build the First Private 5G Testbed in Cambridge Science Park.

in those areas can meet the much needed and referenced critical element in enabling 5G ecosystems. For the U.S., the NTIA should consider ways to ease the contracting challenges and remove barriers to entry through the use of a reference model, smaller procurements, and interoperability testing. This approach and model will better encourage startup and small parties to participate in smaller scale, niche areas of 5G development and drive innovation.

Continue to enable the Federal Communications Commission (FCC) to open and make available spectrum for private use, which will enable and allow larger deployments of 5G networks. This will in turn lead to larger adoption of 5G ecosystems. The successful allocation of spectrum is not solely a U.S. problem;[37] countries across the globe are facing this challenge. It has been one of the major, if not the most significant, stumbling blocks encountered in the effective development and deployment of 5G technology. Ultimately, this has greatly affected the widespread adoption of 5G across the government, commercial, and consumer bases. Increasing the scope and scale of U.S. 5G R&D investments will help to identify new technologies and algorithms to more effectively use existing spectrum.

[37] **Danny Crichton** (August 2020), Trump Administration Announces Major Midband Spectrum Auction for 5G, TechCrunch.

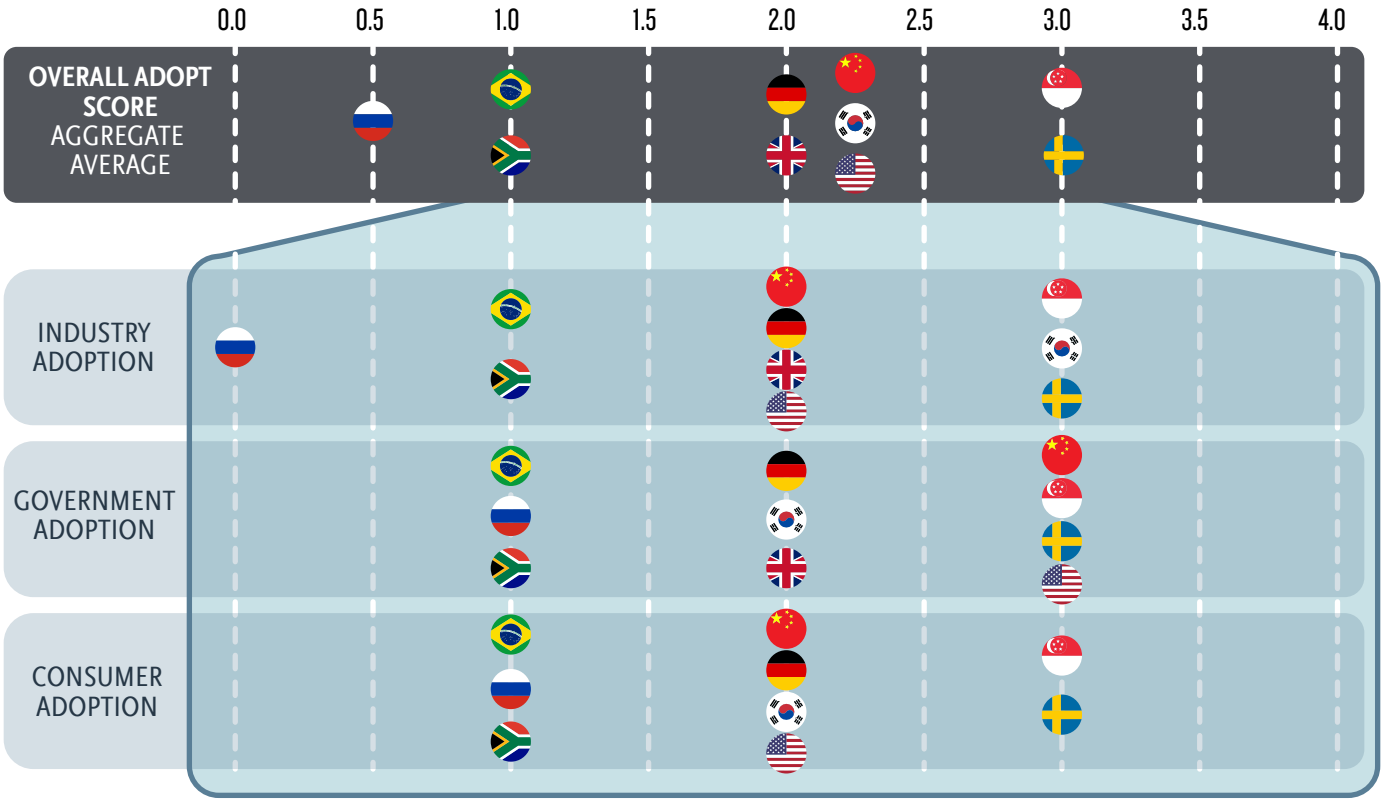


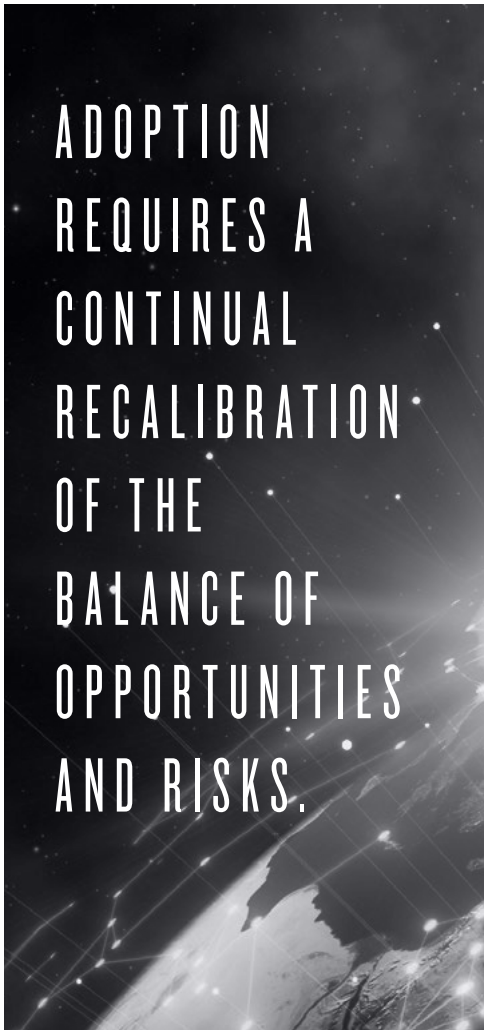
Figure 14: Adopt Layer Scorecard

Adopt

Widespread adoption is the key to stabilizing long-term economic growth. Adoption of 5G technologies across government, business, and individual consumers operationalizes the deployed infrastructure and brings the 5G ecosystem of data-connected devices to life. However, as more users adopt 5G devices and connect to the network, the attack surface will continue to expand. Adoption requires a continual recalibration of the balance of opportunities and risks. Countries that can accelerate adoption and promote new business models will likely experience more economic growth than countries that cannot.

Research indicated that widespread adoption is limited by lagging national 5G network deployments, and slow development of 5G-enabled devices. Competition between industries exists and could slow the rapid adoption of 5G ecosystems as they mature.

We recommend several initiatives to help the U.S. accelerate adoption and promote new business models to unlock economic growth. The U.S. should scale and fund programs to find effective use cases for 5G technologies to jumpstart widespread adoption. We also recommend leaders at the federal and SLTT levels embrace and promote full adoption and employment of 5G ecosystems across the nation, while remaining mindful of pushback from legacy companies that will be threatened by 5G offerings.



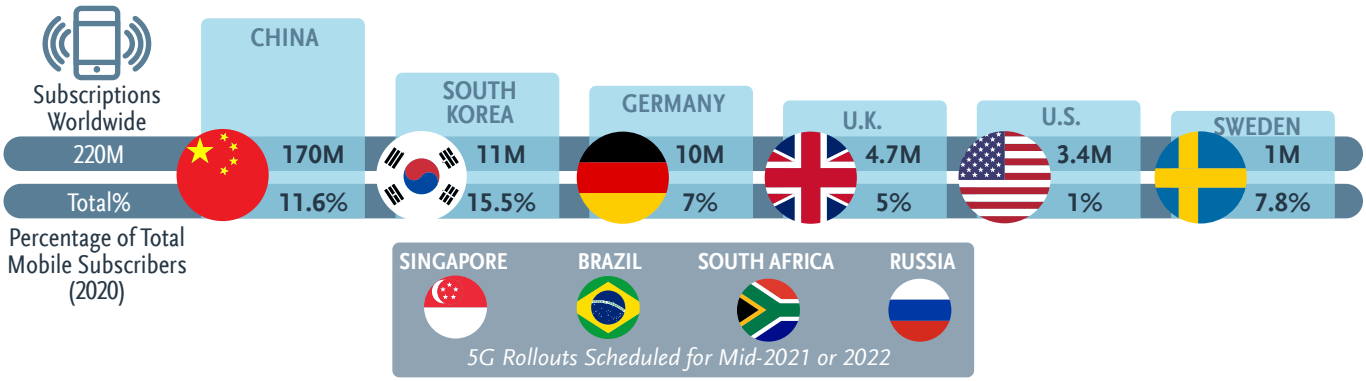


Figure 15: Number of 5G Subscriptions Across Benchmarked Countries

BENCHMARKING FINDINGS AND INSIGHTS

Consumer adoption is still largely limited by a lag in national deployments of 5G networks and slow development of 5G devices. Widespread adoption of new technological evolutions is reliant on the development and deployment of new networks and devices, and many benchmarked countries, including Brazil, South Africa, and Russia have not matured enough through the previous layers of the 5G Power Framework to reach adoption. Deployments drive adoption while also stimulating additional acceptance of the advancements; therefore, network providers deploy networks and the device manufacturers follow suit. Globally, there is hesitance to deploy 5G networks because of costs of upgrading, national security concerns, and lack of political desire in some cases, which in turn has the expected trickledown effect of slowing the development and deployment of devices and true adoption of the 5G ecosystem. The COVID-19 pandemic also hindered the supply and demand for consumer 5G services, compounded by the issue that consumers are not inclined to spend more overall for the service upgrade and that capacity increases face corresponding price erosion.[38] The primary exception to this trend is China. China has experienced a faster-than-expected uptick in 5G adoption—reportedly adding 4.19 million subscribers in February 2021, bringing its total number to 173.16 million, up from 15.4m in 2020, more than a 1000% year-over-year increase—driven in part by consumer access to a greater variety of cheaper 5G devices.[39]

Industry adoption is the primary target for telecommunications operators. Many telecommunications companies worldwide understand that the main growth opportunity in 5G will not be solely focused on enhanced mobile broadband for consumers but instead will rely primarily on industry adoption. Adoption by the private sector—specifically manufacturing, distribution, public transportation and associated transit hubs—stimulates further national economic development and promises far more business opportunity through opening availability to far more differentiated services and new avenues for innovation on 5G networks.[40] A survey by Nokia covering IT decision makers in the U.S. and the U.K. found that energy and manufacturing are the two sectors most inclined to adopt 5G technology in the near term and discovered many businesses in these sectors are already privately exploring advanced use cases for cloud robotics, remote machinery, and infrastructure maintenance.[41] In fact, in the industry setting, the COVID-19 pandemic may even accelerate adoption to overcome the challenges of increased remote connectivity and a high demand for faster production.

Countries are beginning to leverage public-private partnerships to fuel adoption nationwide and across borders. To overcome the technical, geopolitical, and functional barriers to adoption, shown in Figure 16, national governments must form creative partnerships and build funding models to incentivize the private sector and scale-up adoption. Early public-private partnerships in 5G started in 2015 in China and the EU, with the European

TYPES OF BARRIERS TO ADOPTION	SPECIFIC BARRIERS	COUNTRIES EXPERIENCING THESE BARRIERS
Technical	• Spectrum allocation is slowing deployments. • Partial deployments in rural areas limit ability to operate true 5G speeds and latency.	
Geopolitical	• U.S. pressure campaign to ban Chinese hardware impacting deployments.	
Functional	• 5G is lacking a killer application that will increase consumer demand and drive societal adoption. • Decision whether to use proprietary brand or ORAN technologies has stalled development and deployment. • Limited 5G R&D and prototyping support to drive adoption.	

Figure 16: Barriers to 5G Adoption

[38] **European Telecommunications Network Operators' Association** (2021), The State of Digital Communications.
[39] **Ericsson** (2020), Ericsson Mobility Report.
[40] **European Telecommunications Network Operators' Association** (2021), The State of Digital Communications.
[41] **Capacity** (2020), Energy and Manufacturing Lead 5G Enterprise Adoption.

Public-Private Partnership on 5G and China forming the IMT-2020 (5G) promotion group to seed R&D and adoption. These two organizations planned to partner with each other through an industrial agreement to encourage cooperation across borders,[42] but geopolitical pressures to combat Huawei have reversed this course. In the U.S., the Department of Defense has almost tripled spending on Other Transaction Authority (OTA) contracts and partnerships with industry, called consortia, to stay ahead of China. One such OTA has been awarded to the National Spectrum Consortium—an organization made up of 260 members ranging from universities to startups to giant corporations—to pilot 5G projects related to radar and radio spectrum management, smart warehousing, and other functions.[43] Countries will need to continue to leverage these partnerships to expedite 5G use cases and fund innovative ideas to feed adoption.

U.S. POLICY RECOMMENDATIONS

Leverage existing procurement options to establish programs to identify widespread use cases for 5G technologies. Federal government agencies (e.g., Dept. of Energy, Dept. of Health & Human Services, Dept. of Transportation, Dept. of Homeland Security, Federal Aviation Administration, Transportation Security Administration, Advanced Research Projects Agency–Energy) that have OTAs or similar funding mechanisms to research and prototype should look to emulate the concepts and innovative stance the Department of Defense takes to the development, deployment, and adoption of 5G technologies. While OTAs will be critical to success, the U.S. should also explore expanding traditional options for acquisition under the Federal Acquisition Regulation (FAR) and Defense Federal Acquisition Regulation (DFAR). The U.S. government can champion the swift adoption of 5G countrywide by funding 5G pilot programs and prototyping and 5G use case testing for holistic and secure 5G solutions development, deployment, and adoption of 5G technologies. In addition to bolstering the NTIB, seeding R&D programs will help drive adoption across government and into business and society.

Leaders at SLTT levels should embrace and promote full adoption and employment of 5G ecosystems across the country while remaining mindful of pushback from legacy companies that will be threatened by 5G offerings. This requires the U.S. to focus on adoption from the bottom up, where governors, mayors, county officials, and others in local leadership drum up excitement about 5G in their immediate communities and among small businesses. Legacy companies might voice dissent on deployment and adoption strategies of new technology to minimize the loss in revenue they expect to see if they do not adapt to the changing times. While this may be the case, the full adoption of holistic 5G ecosystems at the national and SLTT levels will benefit not only those providing the services but also society as a whole. To overcome this hurdle and promote grassroots support for 5G adoption, the U.S. must launch a massive awareness campaign championed by the federal government to instruct SLTTs on the benefits of 5G and how their communities can leverage this technology to dramatically scale-up their operations and make their communities more profitable and efficient.

Leverage additional private-public partnerships (PPP) including collaboration with other PPPs internationally, to fuel adoption across the government, industry, and consumer sectors. There are many opportunities for the U.S. to leverage these partnerships more effectively to evolve existing adoption campaigns across all three sectors. As a first step to improve the PPP system, the Department of Commerce should begin to fund partnerships like the National Institute for Standards and Technology Advanced Manufacturing Technology Consortia Program launched in 2013 as a grants program created to address high-priority research challenges related to manufacturing—to select pilots for use cases of 5G, AI, and IoT technologies to power industries of the future.[44] In addition, the Department of Defense should attempt to partner with defense bodies of NATO nations for military use cases to promote government adoption that can be interoperable and universally accepted. This could be a loose partnership, focusing only on sharing best practices and lessons learned, or a more formal collaboration that compiles funding for R&D and creates joint ventures to fuel adoption across all markets. With the successes emerging from Europe's 5G PPP and China's IMT-2020, it is clear additional attention must be given to budding private-public partnerships in the U.S.

[42] **5GPPP** (2015), IMT-2020 (5G) Promotion Group and 5G PPP Announce Memorandum of Understanding for 5G.
[43] **Sydney J. Freedberg Jr.** (2019), Pentagon Prototypes 5G With Innovation On-Ramp, *Breaking Defense*.
[44] **NIST** (2019), Advanced Manufacturing Technology Consortia (AMTech) Program.

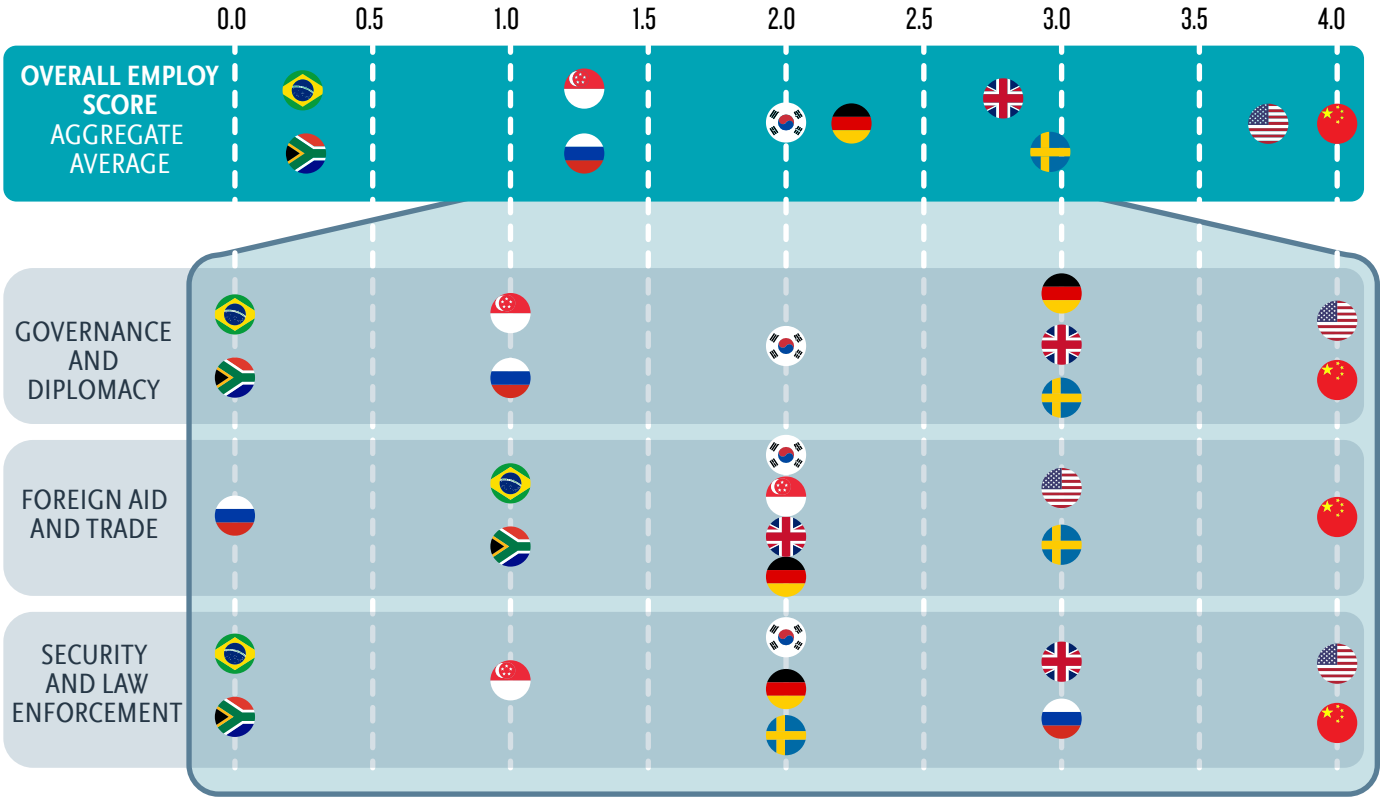


Figure 17: Employ Layer Scorecard

Employ

Countries that employ 5G for national applications are better positioned to exert influence across a spectrum of hard and soft power that spans security and law enforcement, foreign aid and trade, and governance and diplomacy. Research indicated that 5G has not yet been developed, deployed, and adopted at a scale that would allow a country to employ it to purposefully manage risk, exert influence, and strengthen national security. International standards organizations—in addition to being near-term mechanisms to create and enforce 5G policies and norms—are opportunities for countries to set and shape the 5G agenda in a direction that advances its national interests.

Research found that China, followed closely by the U.S., is best positioned in the "Employ" layer, depicted in Figure 17, to leverage 5G to advance national interests through a spectrum of hard and soft power capabilities. China employs a soft power approach that focuses heavily on foreign aid and trade, specifically aimed at supplying much of Asia and Africa with 5G infrastructure at a reduced cost. China has also taken an increasingly active role in shaping international telecommunications standards, especially with respect to facial recognition technology, in an effort to normalize its controversial domestic security and law enforcement priorities. Because of security concerns, the U.S. has favored a harder power approach, aimed at pressuring partner nations to ban Chinese hardware in international 5G deployments. While this strategy has been somewhat successful, it lacks economic incentives and other soft power approaches to form more favorable foreign aid and trade relationships. More recently the U.S. has launched initiatives and introduced legislation aimed at leveraging its network of allies and partner nations to counter China.

We recommend that the U.S. retake global technology leadership. It can do so by offering 5G infrastructure packages in support of diplomatic relations in targeted regions, and increase leadership and involvement in international standards organizations to develop 5G laws and norms that address national security concerns, stimulate domestic economic growth, and reestablish U.S. leadership abroad.

BENCHMARKING FINDINGS AND INSIGHTS

Few countries have developed, deployed, and adopted 5G at a scale that would allow it to employ the technology for national applications (except for the U.S. and China). Most of the benchmarked countries have not made enough progress across the first four layers of the framework to have capability to employ 5G for broader geopolitical gains. To do so, countries will likely need to demonstrate strong capabilities across the first four layers of the framework. Strong national laws, policies, and standards can serve to enhance a nation's influence on

international governance and diplomacy. A strong NTIB, domestic manufacturing capacity, and strong national adoption can enhance a nation's favorability as a foreign trade and aid partner. Strong R&D, development, and deployment capabilities have many security and law enforcement applications. This is still an evolving area to watch as countries advance along the maturity curve.

The U.S. and China are vying for influence over international governance and diplomacy. In past years, the U.S. took a less active role in creating the policies and norms that helped guide the innovative, ethical, and societal uses of technology. This decline in U.S. leadership and engagement within international standards organizations has resulted in allies, adversaries, and international organizations charting their own path in the absence of U.S. leadership. Further fragmentation of the standards organizations and the laws, policies, and standards they champion risk diminishing their effectiveness.

China's foreign aid and trade strategy aims to build out a significant portion of global 5G infrastructure. China's "One Belt, One Road" strategy is an expansion initiative to partner with 70 nations and international organizations to develop global infrastructure. As part of this strategy, China aims to connect developing countries in Asia and Africa with 5G technology.[45] This infrastructure plan, in conjunction with China's 5G diplomacy governance, positions China to control a large portion of the global communications market.

The U.S. has taken steps to limit Chinese expansion but needs more worthwhile incentives to empower favorable trade and economic relationships. The U.S. strategy under the Trump administration was essentially a pressure campaign. It leveraged diplomatic relations with allied nations to prohibit the use of Chinese equipment in national 5G networks in Australia, New Zealand, and Japan. Taiwan is considering imposing similar bans, and the U.K. and France have reversed course and are in the process of removing Huawei equipment from existing 5G networks. In keeping with this strategy, the Biden administration recently imposed tighter export restrictions on Huawei equipment.[46] However, despite the risks being well known, other countries are still opting to use Chinese equipment, in part because of a lack of other political and economically viable options.

More recent steps by the U.S. aim to counter China by leveraging its strong network of allies and partners. The U.S. recently launched the Clean Network Initiative to protect citizens' privacy and companies' sensitive information on 5G mobile networks in 53 countries and territories,[47] and an aid and foreign assistance program to help partner nations offset the cost of purchasing trusted 5G network component parts.[48] The Democracy Technology Partnership Act, a bill introduced in the Senate, aims to counter China by promoting greater coordination, common functional problem-solving institutional mechanisms, and more compatible legal regimes among democratic nations.[49] In the past, the U.S. strategy of leveraging the strength of its alliances has been an effective means to address shared threats and derive mutual benefits.

U.S. POLICY RECOMMENDATIONS

Offer 5G infrastructure and development packages in support of diplomatic relations in targeted regions. The U.S. has used a "stick approach" in an effort to counter Huawei but now must balance it with a "carrot" approach to ensure an aid and trade strategy. U.S. Agency for International Development (USAID) offering cash incentives to offset hardware costs is a good start. The U.S. should continue to offer additional economic incentives to help allies and strategic partner nations deploy 5G networks, unilaterally and through bilateral and multilateral partnerships. The U.S. can more effectively counter China's "One Belt,

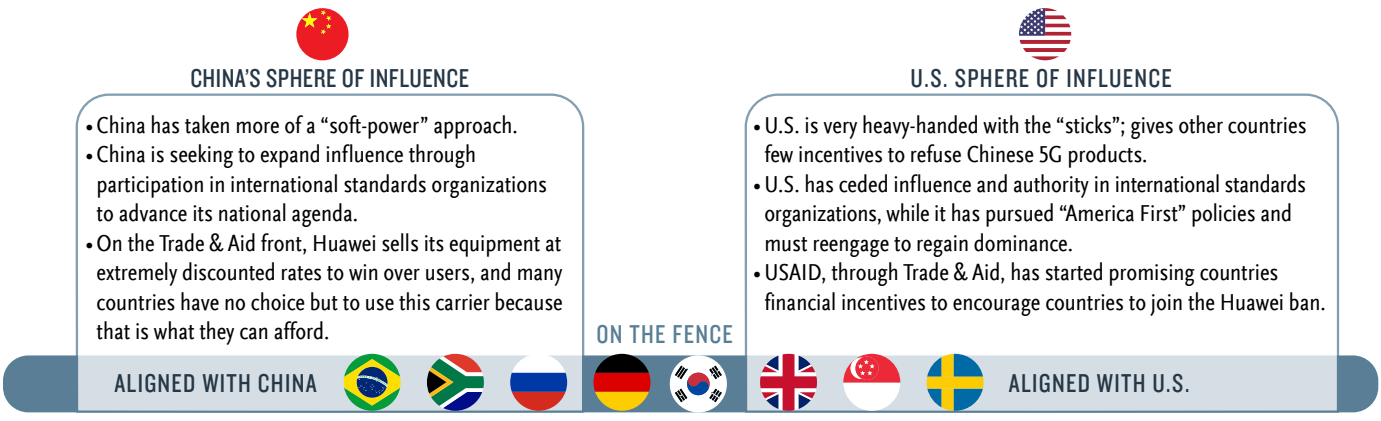


Figure 18: U.S. vs. China—Combating Spheres of Influence

[45] **DW**, (2019), Will China's 5G Digital Silk Road Lead to an Authoritarian Future for the Internet?
[46] **Eric Martin** (2021), U.S. Imposes New 5G License Limits on Some Huawei Suppliers, *Bloomberg*.
[47] **Leigh Hartman** (2020), Expanded Clean Network Initiative Safeguards Data, U.S, *Bloomberg.U.S. Embassy in Georgia*.
[48] **FCC** (2020), FCC, USAID to Collaborate on International 5G Deployment and Security.
[49] **S.604, 117TH Cong.** (2021), A bill to authorize the establishment of a Technology Partnership among democratic countries, and for other purposes.

One Road" initiative by enabling economic growth in developing countries through expansion of 5G ecosystems.

Increase leadership and involvement with international organizations and continue developing global 5G laws and norms. In doing so, increased involvement will help to address U.S. national security concerns, stimulate domestic economic growth, and establish the U.S., once again, as a critical and trusted global leader. In the past, this leadership was just one of the ways the U.S. cemented itself as a global power. It placed its most capable and thought-provoking leaders, in technology, in positions supporting these international organizations. This helped foster faith and trust, while instilling confidence in U.S. leadership. Repositioning leaders in these organizations, in addition to grooming an entirely new generation of leaders who deeply understand and promulgate the importance of technology beyond its obvious daily applications, will signal that the U.S. is committed to taking back the torch in thought leadership and technological advancement.

Continue to grow the Clean Network Initiative Coalition and construct a multi-year strategy focusing on regaining U.S. influence in standards organizations. This strategy would help build U.S. prominence and serve as an excellent counter to China's Standards 2035 agenda—a 15-year blueprint laying out China's plans to set the global standards for next-generation technologies.[50] This 3–5 year strategy should be drafted immediately by the National Telecommunications and Information Administration in coordination with U.S. private-public partnerships and be brought to the coalition of countries formed by the Clean Network Initiative. The U.S. should make an effort to bring Asia-Pacific nations—those with open internet connectivity models that align with Western values—into the fold of this Clean 5G coalition.

[50] **Wall Street Journal, Valentina Pop et al.** (2021), From Lightbulbs to 5G, China Battles West for Control of Vital Technology Standards.

CONCLUSION

5G is still an emerging technology. Longer and more expensive build-out times than previous mobile computing evolutions (i.e., 1G–4G) means it will still be several years before it reaches full maturity. Countries that are first to reach full maturity will be best positioned to leverage 5G to advance strategic domestic and international interests.

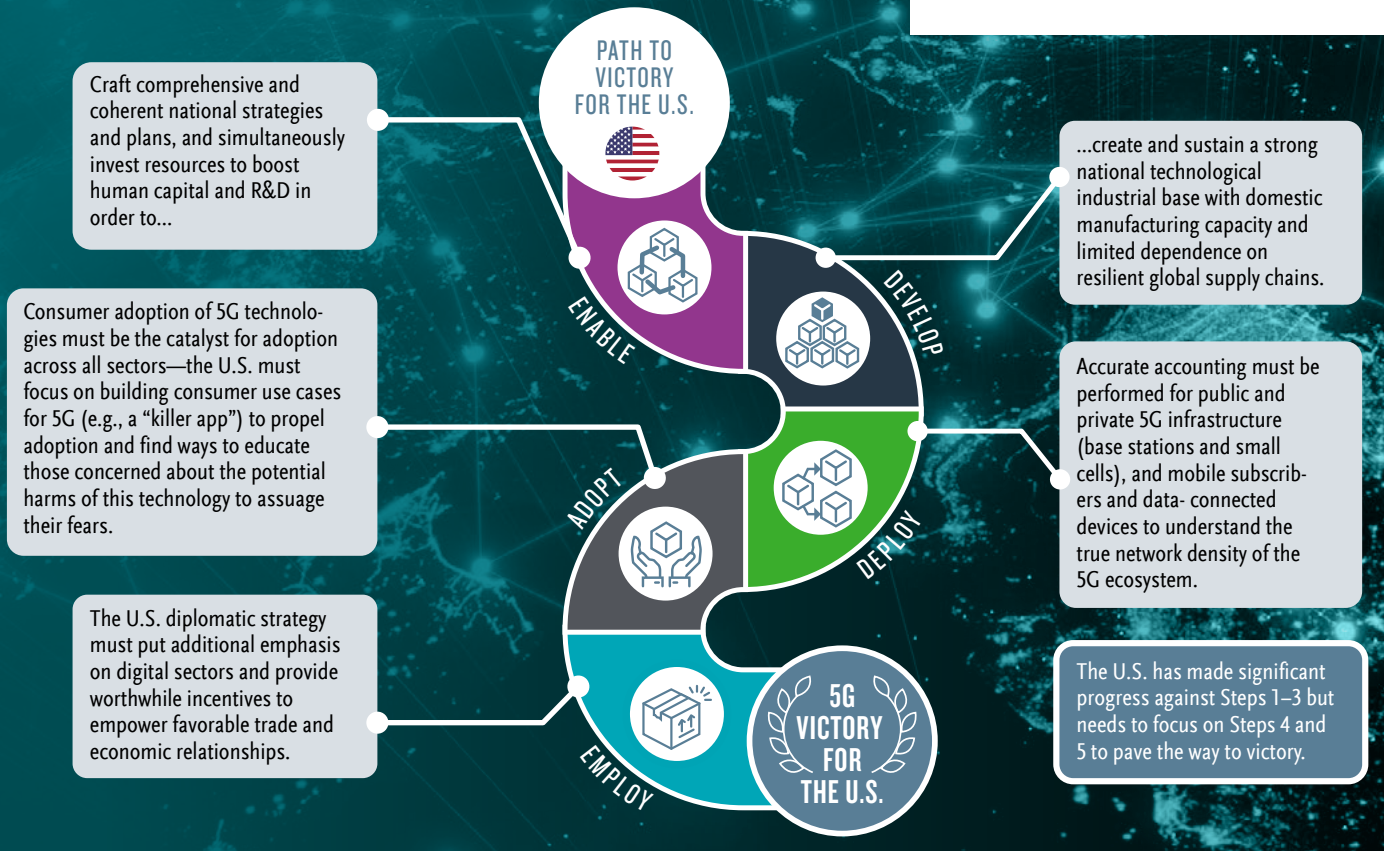
Counter to widespread reports, the U.S. is not hopelessly behind China. The 5G race is certainly underway, but no clear winner has emerged. "Winning" will mean more than being the first to massively deploy a 5G backbone. A range of national capabilities is needed to capitalize on this novel technology.

Our 5G Power Framework revealed that the U.S. possesses many fundamental strengths necessary to win the race. The U.S. produces the most skilled cyber human capital through many training and education pathways, is a leader in chip design, and has advocated for international clean networks and trusted 5G component parts. At the same time, the U.S.'s capabilities have several glaring gaps. The U.S. lags in relative R&D funding, its skilled software engineering talent pool is insufficient, and its domestic manufacturing of key 5G technologies is limited. The U.S. has also taken a backseat at global standards organizations.

The U.S. must adapt policies to fill those gaps and position the country to dominate and thrive in the 5G era. The U.S.'s successes in developing a modern informatized nation over the past half century can be repeated. Its economy can run more efficiently; its military can act with even more agility and insight; its credibility as an innovator can grow further, showing that the U.S. is a country worthy of emulation, immigration, and investment.

THE PATH TO VICTORY IN THE 5G RACE WILL REQUIRE:

- **Strengthen the Foundation (Enable):** Comprehensive and coherent national strategies, plans, investments, and a strong NTIB that enables leadership in and access to 5G technologies
- **Develop the National Industry (Develop):** Investment in domestic advanced production capacity and limited dependence on global supply chains that will allow the U.S to create a home-grown 5G industry and initiate progress in development.
- **Ensure Infrastructures are Secure and Resilient (Deploy):** Public-private infrastructure partnerships to create holistic opportunities to deploy 5G technology. Engagement with SLTTs and the consumer market segment to drive widespread national adoption.
- **Accelerate Adoption and Promoting New Business Models (Adopt):** Engagement with SLTTs and the consumer market segment to drive widespread national adoption.
- **Retake Global Leadership (Employ):** Targeted and sustained diplomatic engagement with partner nations that will empower states to leverage 5G for mutual benefit.



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