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Building Back Better with Distributed Computing

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Summary

The United States can create jobs, better compete against China, and at the same time address major social challenges if it leverages the emerging combination of technologies that will constitute "distributed computing" to enable new, democracy-enhancing 21st century infrastructure.

Three technologies—the Internet of Things, 5G, and artificial intelligence (AI)—will increasingly come together to compose a new digital revolution. The resulting distributed computing will function as a hugely enhanced combination of the smartphone and the cloud, or as a computer network in a box. It can unlock massive opportunities if the United States invests at home and works with allies to protect democratic values. Distributed computing can solve some of the country's long-term challenges in climate, healthcare, transportation, and energy.

From the United States' birth, networks that link its vast number of individuals, companies, and communities in new ways have served as "platforms" for innovation and opportunity—including canals for shipping, post roads, railroads, highways, electric grids, pipelines, the telegraph, telephony, and the Internet.

Distributed computing can only help address critical social challenges with public investment and effort. With that support, the platforms enabled by distributed computing can provide tangible benefits to the built environment, jobs, and critical services around the country at lower cost than existing models for renewing the United States' infrastructure, notably in the following sectors:

Clean power: Distributed-computing technology can drive improvements in the distribution and measurement of power generation and, through applications like load balancing, can mitigate greenhouse-gas emissions.

Transportation: Advances in distributed-computing technology will play a critical role in transitioning to a fleet of autonomous electric vehicles and it has the potential to drive innovations in road and highway infrastructure.

Water: Distributed-computing technology provides the opportunity to improve the functionality of the aging sewage and pipe systems that undergird U.S. cities.

Healthcare: Distributed-computing technology will drive improvements in healthcare by dramatically improving the delivery of innovative e-health applications like telehealth.

Education: Distributing computing can help improve student outcomes by providing teachers with new educational tools and providing adaptable educational programming for students.

In order to capture the benefits of distributed computing, the United States must invest at home and reassert its position as a global tech leader, working with allies to ensure that new technologies are deployed with respect to human rights and democratic values. To accomplish these aims, the following policy agenda should be adopted.

Investment in research and development (R&D): U.S. investment in R&D has flattened as a share of GDP. To ensure that government agencies have the resources and encouragement necessary to drive innovation, the United States must reverse this trend and recommit to investing in R&D.

Science and talent: Beyond R&D expenditure, the United States must develop its workforce by increasing investments in education in science, technology, engineering, and mathematics, and reorient immigration law to ensure the United States can recruit technologists from across the world.

Supply-chain security: Particularly in critical industries, the United States must ensure that the supply chains do not undermine national security or give comfort to those who would undermine the open Internet or the global trading system.

New rules of the road for the digital era: To ensure that the externalities of technological deployment are

not offloaded onto individuals and society, the United States must update offline civil rights, privacy, competition, campaign finance, and cybersecurity policies, and create new guardrails for the use of these technologies.

Modernizing government and creating new institutions for the digital age: The federal government must improve its capacity to administer services, which may require new institutions outside government, new systems within government, and a new willingness to engage in multi-disciplinary collaboration.

Improving global leadership: To ensure that emerging technologies are deployed with respect for human rights, security, and democratic values, the United States should join forces with allies and coordinate on technological deployment and standards setting.

Introduction

The United States confronts challenges unprecedented in scale, scope, and complexity. Never in its history has the country suffered simultaneously a pandemic, an economic slump, and widespread distrust of democratic processes. Underlying this triad of trouble are the escalating problems of inequality, racism, world disorder, and climate catastrophe.

As President Joe Biden embarks on a project to "build back better" to recover from these crises, recent technological advances can unlock possibility. Leveraging these new technologies can not only help break the deadlock on investment in the nation's infrastructure and public systems by making those systems more efficient and less expensive. It can also create a market for critical technologies helping the U.S. improve its competitive position vis a vis China and creating new technology jobs.

The story of innovation in the United States has been one of building networks that connect its vast number of individuals, companies, and communities in new ways. In the past, these networks, have served as "platforms" for private market innovation. They have included shipping, post roads, railroads, highways, electric grids, pipelines, the telegraph, telephony, and the Internet. Each has boosted productivity and spurred private sector innovation. As the incoming Biden Administration looks to create jobs, increase productivity, and regain America's competitive edge, it should "build back" a better platform that undergird society and the economy.

The Internet and related digital technology—referred to here as "infotech"—is the communications platform that has defined our age. Like previous means of exchanging information, it expanded opportunity and wealth as the network connected more people but, as has happened in the past, policy failed to keep up. Power became centralized, creating winner-take all economics, and vulnerabilities were exploited by malign actors and competitors —weakening the country's economy, security, and society. Meanwhile, China mobilized not only to gain an advantage but also to increase the ability of governments to restrict market entry and to censor and surveil their own citizens.

But the platform is changing—and this creates an opportunity for the United States to repair the damage and usher in a new era of opportunity—if it acts strategically.

In the 2020s, three technologies will come together to transform infotech. In the aggregate they will define what can be generally described as distributed computing, ranging in form from Fitbits to in-building computer centers. The first, the Internet of Things (IOT), codes the physical world. The second, 5G, collects that data and transmits it to distributed computing loci, whether carried by people, housed in basements, or embedded in machinery. When applied to this data, the third, artificial intelligence, will enable staggering advances in industry and society. Taken together, distributed computing can be thought of as a massively enhanced combination of the smartphone and the cloud, or as a computer network in a box. This new iteration of infotech offers enormous potential for economic and societal benefit.

As President Joe Biden embarks on a project to "build back better" to recover from these crises, recent technological advances can unlock possibility.

Distributed computing can spawn new platforms. These include the digital versions of physical infrastructure that is aging and failing to meet 21st century challenges, notably clean power, transportation, and water and sewage. They also include health and education—two critical social systems that can be transformed by digital infrastructure to provide empowering platforms for professionals (teachers, healthcare providers) and service recipients (students, patients, communities). These new platforms, like the epochal ones before, are more than the basis for an industrial policy or for competing with China; they also address social goals like winning the battle against

climate catastrophe and creating a fairer distribution of wealth and benefits.

Responding to these new challenges will require Americans' ability to acknowledge, in the words of President Abraham Lincoln, the need for government to "do for a community of people whatever they need to have done, but cannot do…for themselves."[1] Lincoln mobilized the country to save American democracy and also, as the only president to earn a patent, he leveraged the major platforms of his day—the railroad and the telegraph—to link the nation that dominated the industrial age. And it will require updating rules—for competition, privacy, consumer protection, civil rights, elections, and cybersecurity—to adjust incentives to prioritize the safety of users, communities, and democracy.

Coordinated Policy Ensured Early Infotech Benefited the United States and the World

U.S. Policies Supported the Pre-Internet Computing Revolution

The federal government played a significant role in driving the transition from traditional industry to the modern information-technology economy. Coming out of the Second World War, the U.S. Army—which in 1946 introduced the Electronic Numerical Integrator and Computer, the first programmable general-purpose computer[2]—and the Office of Naval Research (ONR) conducted research that served as the basis for computer design and computer processing.[3] The patchwork of federal investments across an array of governmental institutions—including the ONR, the National Science Foundation, the Advanced Research Projects Agency (ARPA, DARPA), and the National Aeronautics and Space Administration (NASA)—made crucial contributions in areas like semiconductors and relational databases.[4] In the 1950s, the Department of Defense supported 25 percent of the transistor research carried out at Bell Laboratories.[5] The Department of Justice's 1956 consent decree against the Bell System played a significant role in diffusing critical technologies like the transistor by requiring Bell to license its patents royalty-free.[6] In 1959, Bell Labs introduced the MOSFET (metal-oxide-semiconductor field-effect transistor), which became the "base technology of late-twentieth century and early-twenty-first-century America."[7] From 1949 to 1959, federal funding accounted for 59 percent of the combined computer-related research and development spending of General Electric, Sperry Rand, AT&T, Raytheon, RCA, and the Computer Control Corporation.[8]

Fairchild Semiconductor, arguably the first company of the modern Silicon Valley, was a significant beneficiary of government support. It helped launch the careers of the founders of Intel, the company whose innovations made possible the personal computing industry.[9] The Xerox Alto, the first personal computer to support a graphical user interface,[10] created at the Palo Alto Research Center from ARPA- and NASA-funded research at Stanford,[11] led to the Apple Lisa, the first commercial computer with a graphical user inter-

1 Abraham Lincoln, Fragment on Government, July 1, 1854.

2 Kira R. Fabrizio and David C. Mowery, "The Federal Role in Financing Major Innovations: Information Technology During the Postwar Period," in N. R. Lamoreaux and Kenneth L. Sokoloff (eds), Financing Innovation in the United States 1870 to the Present, MIT Press, 2007.

3 National Research Council, Funding a Revolution: Government Support for Computing Research, The National Academies Press, 1999.

4 Ibid.

5 Ibid.

6 Martin Watzinger et al., How Antitrust Can Spur Innovation: Bell Labs and the 1956 Consent Decree, Centre for Economic Policy Research, November 3, 2016.

7 Ross Knox Bassett, To the Digital Age: Research Labs, Start-Up Companies, and the Rise of MOS Technology, The Johns Hopkins University Press, 2002.

8 Kira R. Fabrizio and David C. Mowery, The Federal Role in Financing Major Innovations: Information Technology During the Postwar Period..

9 Alfred D. Chandler Jr., Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries, Harvard University Press, 2001.

10 John C. Abell, "Jan. 19. 1983: Apple Gets Graphic With Lisa," Wired, January 19, 2018.

11 National Research Council, Funding a Revolution: Government Support for Computing Research.

face.[12] Altogether, the federal government financed more than 60 percent of all university research in computer science and electrical engineering from the mid-1970s to the mid-1990.[13]

Smart Policy Spurred the Open, Global Internet

The second era of infotech began when these computers were connected. Famously, the Advanced Research Projects Agency Network created the Internet's predecessor, "ARPANET," the first wide-area packet-switching network with distributed control, in 1969. Further research at ARPA and Stanford University in the 1970s evolved into the Transmission Control Protocol (TCP) and Internet Protocol (IP), the two protocols of the Internet protocol suite. In the early 1980s the National Science Foundation funded national supercomputing centers at several universities and provided connection among them.

The National Science Foundation also developed transformative inventions like the global positioning system and the graphical user interface,[14] and it has served as a catalyst for private-sector innovation. Federal grants and fellowships supported innovators like Larry Page and Sergey Brin, who created Google.[15] In fact, almost one-third of U.S. patents rely on federal research.[16] Even after Republicans and Democrats agreed that "the era of Big Government [was] over," as President Bill Clinton famously declared, policymakers pursued a vision that would result in an open, global digital network.

Washington's influence on the fledgling Internet included the Omnibus Budget Reconciliation Act of 1993, which not only implemented budget-balancing measures that were credited with keeping interest rates down throughout the 1990s, but also authorized the Federal Communications Commission (FCC) to begin the first auctions of the valuable airwaves.[17] This allocated scarce spectrum to more efficient and effective use than the previous models of granting spectrum to those with the best Washington contacts. The result was a half-dozen U.S. digital cellular companies and the growth of a new industry.

At about the same time, a few technological breakthroughs created the potential for easy consumer use of the Internet. The FCC made the momentous decision to allow Internet access providers to use the landline telephone network as their initial network without paying money to the telephone companies.[18] It implemented the Telecommunications Act of 1996 to remove barriers to infrastructure investment, promoting competition in the telecommunications market and helping create incentives for tens of billions of dollars in broadband and network investment.[19] The FCC also created a "public option"—the E-Rate, a program that provided over $2 billion a year to fund connections to kids in classrooms and libraries, with more going to the poorest and most rural areas. Separately, Section 230 of the Communications Act was enacted, ensuring that new "intermediary" companies would have limited liability for the content they carried, even if they moderated that content. At the international level, the United States supported "multi-stakeholder governance" (involving the government, the private sector, and civil society) for technical rules for the new technology, including through the Internet Corporation for Assigned Names and Numbers (ICANN), the Third Generation Partnership Project, the Internet

12 Alfred D. Chandler Jr., Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries, Harvard University Press, 2001.

13 Jacob S. Hacker and Paul Pierson, "Why Technological Innovation Relies on Government Support," The Atlantic, March 28, 2016.

14 Defense Advanced Research Projects Agency, DARPA: 60 Years 1958-2018, September 5, 2018.

15 National Science Foundation, On the Origins of Google, August 17, 2004.

16 Matt Hourihan, "Public Research Investments and Patenting: An Evidence Review," American Association for the Advancement of Science, May 2020.

17 Federal Communications Commission, About Auctions.

18 Federal Communications Commission, 1997 Access Reform Order, May 16, 1997.

19 Charles B. Goldfarb, Telecommunications Act: Competition, Innovation, and Reform, Congressional Research Service, June 7, 2007.

Engineering Task Force, and the Institute of Electrical and Electronics Engineers.

The new decentralized, open Internet platform grew, connecting computers across the United States and around the world, along with the new rules and governance model. The cadres of American engineers who attended the long meetings of the standard-setting bodies were evangelists for openness, innovation, and freedom as were the diplomats sent to the inter-governmental organizations, including the World Trade Organization, the International Telecommunications Union (ITU), and the Organization for Economic Cooperation and Development. The United States negotiated in these venues to clear out outdated rules that stood in the way of the new global network. U.S. Trade Representative Charlene Barshefsky negotiated the Information Technology Agreement of 1996, which eliminated tariffs on information technology connected to or used by the Internet.[20] This opened the door to the rapid diffusion of U.S. technology around the world. And through the Agreement on Basic Telecoms of 1997, and its regulatory side agreement, more than 60 countries committed to let the fiber-optic cables carrying the Internet cross their borders.[21]

Infotech—the computers, computerized machinery, fiber-optics, communication satellites, the Internet, and other tools—became a significant part of the world economy, changing many businesses and industries. The infotech revolution (combined with lower interest rates and supports for low-income families) helped drive improvements in U.S. productivity, which had languished since the late 1970s, lifting living standards, shrinking poverty, and democratizing the ability to innovate and create. Together they helped produce a budget surplus and the "dot.com" stock market boom. Fortunes were made and U.S. industries put paid to Japan's dominance of electronics in the 1980s. Intel became the world's largest semiconductor firm and Microsoft the biggest software company.

U.S. firms had fused digital cellular technology and the Internet. As this shift occurred, U.S.-based mobile operating systems became the new de facto platforms of the Internet.

Even once the 1990s boom ended and many early companies failed, progress did not slow. When the established telephone companies kicked the new competitors off their networks, cable firms in combination with Wi-Fi[22] provided new bandwidth. The new communications technology, for example, enabled Intel to revolutionize portable computing through affordable Wi-Fi enabled laptops.[23] Meanwhile, in one of the most remarkable business transformations in history, the old landline telephone companies dedicated themselves to becoming digital cellular titans and soon hosted handheld computers on to their networks with the introduction of the iPhone in 2007 and then the Android system. U.S. firms had fused digital cellular technology and the Internet. As this shift occurred, U.S.-based mobile operating systems became the new de facto platforms of the Internet.

The economic benefits were felt throughout the world. The digital revolution created new global markets and industries bringing millions in China and low-income countries out of deep poverty. According to one estimate, the expansion of Internet access in developing countries produces a 15 percent average increase in per capita income.[24]

20 Michael Anderson and Jacob Mohs, "The Information Technology Agreement: An Assessment of World Trade in Information Technology Products," Journal of International Commerce and Economics, January 2010.

21 World Trade Organization, The WTO Negotiations on Basic Telecommunications, March 6, 1997.

22 The United States led in creating unlicensed spectrum suitable for Wi-Fi. This helped U.S. firms defeat a European alternative called Hiper-LAN.

23 Intel, Intel Launches Intel Centrino Mobile Technology, March 12, 2003.

24 Deloitte, Value of Connectivity: Economic and Social Benefits of Expanding Internet Access, February 1, 2014

The digital revolution did not only increase productivity and living standards; it also provided new opportunities for expression, assembly, and innovation. But the lesson about governance that was learned was the digital version of the neoliberal belief that markets would naturally make infotech work for society; it seemed the new technology was by its very design not only productivity-enhancing but also democracy-enhancing. The importance of policy choices was forgotten. And as control over the new platform centralized, institutions from journalism to political parties were disintermediated, and support for public investments of any kind—including in infrastructure and research and development (R&D)—disappeared, the policy frameworks were neglected rather than updated.

Social Networks and Rising Authoritarian Challenge

Even during and after the 2007-2009 recession, a third infotech era—characterized by the rise of the smartphone, the cloud, and social networks -- enabled the convergence of communications with computing famously putting a supercomputer in the pocket of ordinary citizens. On the top of this new platform social networks arose. They offered not only a chance to share pictures with family, connect with grade school classmates, and share obscure interests, but the potential to deliver healthcare, education, and widespread productivity gains – though these last have been slow to emerge. U.S. policy embraced the right to Internet freedom in a trio of speeches by Secretary of State Hillary Clinton and funding for tools, services and organizations that assisted people living under authoritarian regimes avoid censorship and surveillance.

The Obama administration pushed back successfully against attempts by China, Russia, and Iran to use the ITU to give back to governments the ability to stop communications at the border's edge.[25] It realized the importance of strengthening multi-stakeholder institutions if it was to convince other countries to reject the autocrats' proposal to carve up the Internet. Since 1997 the United States had kept its hand on ICANN, which manages the unique addresses that allow computers to find each other and the mechanisms for resolving disputes over the rights to domain names and curbing cyber fraud. It gave up that role in 2016 to remove any confusion about U.S. control and to underscore the importance of ICANN's core tenets of bottom-up, consensus-driven, and multi-stakeholder governance[26] rather than state control.

Nonetheless, the Arab Spring quickly turned to winter. Russia and China launched cyberattacks on Western firms and institutions. The Chinese Communist Party worked with China's infotech firms to protect its rule. The smartphone and Internet gave the party all-seeing power. In return for their cooperation, it let Chinese infotech entrepreneurs become fantastically wealthy, like the U.S. tech titans they had imitated.[27]

Meanwhile, China ignored many of the strictures that had been conditions for it joining the World Trade Organization in 2001. Despite its Accession Protocol, it continued to wall off its market from Western competition as much as possible by requiring joint ventures or intellectual-property transfers.[28] China banned many successful American companies completely and created mirror images: with some differences, Baidu as Google, JD as Amazon, Lenovo as Hewlett-Packard. Intel and Apple were able to retain a presence in China because the tangible objects they sold were more difficult to imitate or tap into. "China, Inc."—the cooperative system of Chinese firms, government agencies, and financial institutions—strengthened the power of Chinese infotech giants and autocratic government.

25 Eli Dourado, "Here's Why We Should Go Through with the IANA Transition," Plain Text, June 10, 2016.

26 ICANN, Welcome to ICANN.

27 Adam Hayes, "10 Influential Chinese Entrepreneurs," Investopedia, October 17, 2018.

28 Ted Fishman, China, Inc.: How the Rise of the Next Superpower Challenges America and the World, Scribner: 2006.

Soon China accounted for a fourth of global demand for chips and mobile phones[29] as well as an even bigger share of the global market in end-user products like personal computers and in Internet services like online payments. It even managed to recover quickly from the 2008 financial crisis while Western economies flailed for a decade.[30] In the process it became the world's largest foreign investor—a position that the United States had held since the end of the Second World War.[31]

In the United States, as David Autor, David Dorn, and Gordon Hansen's describe in their work on the "China Shock," American families, especially in former manufacturing towns, saw their incomes flatline as jobs moved overseas.[32]

A divided Congress was unable to deliver investments in the economy—in R&D, infrastructure, or training—to tackle the growing competitiveness challenge.

In the Obama administration's strategic pivot to Asia, the Trans-Pacific Partnership was intended to be a keystone, unifying a dozen Pacific Rim economies into a single trading block. If successful, the agreement would have increased political and economic pressure on China and challenged its ability to dictate the terms of trade in the region. However, the treaty was never approved by Congress. The Obama administration also struck an historic agreement on the Paris Climate Accords that could have formed the basis for increased cooperation.

At home, a divided Congress was unable to deliver investments in the economy—in R&D, infrastructure, or training—to tackle the growing competitiveness challenge. Meanwhile, infotech companies left the economic and societal "externalities" of disinformation, privacy, harassment, and cybersecurity to individual users. The Obama administration sought to update policies that would address the increasing vulnerabilities of the sector. Among other initiatives, it worked to gain agreement on privacy legislation and an updating of consumer protection more broadly. On cybersecurity, it produced a critical agreement with the Chinese government to stop the theft of U.S. companies' trade secrets and intellectual property[33]—dramatically reducing what the National Security Agency Director had called "the greatest transfer of wealth in history,"[34] built cyber threat detection and prevention systems to protect federal agencies,[35] and developed the best-practices framework the National Institute of Standards and Technology, which was adopted by many in the private sector.[36] The administration also made the once provisional U.S. Cyber Command permanent, established international norms in cyberspace,[37] and issued sanctions in response to state-sponsored cyberattacks.[38] But cyber espionage and theft escalated, with China and Russia in the lead, as did the tracking of individuals' personal information. And, of course, in the 2016 presidential election, Russia micro-targeted social-media content to receptive voters in swing states, while the politici-

29 Ted Fishman, China, Inc.: How the Rise of the Next Superpower Challenges America and the World, Scribner, April 11, 2006.

30 In part because the Chinese Communist Party deployed an economic stimulus three-times the size of the U.S. one (adjusted for the relative size of the two economies).

31 Financial Times, "China to Become One of World's Biggest Overseas Investors by 2020," June 25, 2015.

32 David H. Autor, David Dorn, and Gordon Hansen, "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade," Annual Review of Economics, August 8, 2016.

33 Adam Segal, The U.S.-China Cyber Espionage Deal One Year Later, Council on Foreign Relations, September 28, 2016.

34 Josh Rogin, "NSA Chief: Cybercrime Constitutes the 'Greatest Transfer of Wealth in History,'" Foreign Policy, July 9, 2012.

35 Sean Lyngaas, "White House Defends Einstein Firewall," Federal Computer Week, February 11, 2016.

36 NIST, NIST Releases Version 1.1 of its Popular Cybersecurity Framework, April 16, 2018.

37 Danny Vinik, "America's Secret Arsenal," Politico, December 9, 2015.

38 David E. Sanger, "Obama Strikes Back at Russia for Election Hacking," New York Times, December 29, 2016.

zation of race and class divisions was amplified with algorithms favoring "engagement." The communications technologies that seemed designed to promote democracy and make government more accessible had by 2016 contributed to the spread of conspiracy theories and violence, including in the Philippines and Myanmar,[39] as they have more recently in the United States

The Cost of Zero-Sum Policy Response

In recent years, the United States has failed to work with its allies either to create new rules of the road for platforms or combat the abuses of authoritarians. In addition, it is at risk of losing its edge in the technologies of the future. China's government funding for R&D is fast approaching that of U.S. government funding; and, though in the United States businesses do more R&D than government, that money goes mostly toward applied research rather than the research that produces innovation breakthroughs. China is leading the world in AI investment. Its dominance in 5G, the backbone of the coming Internet, is in part because the United States has yet to make spectrum available and has no national producer. China unveiled in 2017 a quantum communications network from Beijing to Shanghai, and it has the leading companies in language processing, speech recognition, computer vision, sensors, and facial recognition. The United States still has enormous assets in core technological tools, such as the tools used to design, build, and train algorithm sets but its investments appear not to be keeping up.

The Trump Administration predicated its trade war—and tariff hikes on over $360 billion in goods—in part on China's Made in China 2025 plan to dominate high-tech manufacturing that was coupled with intellectual-property theft, including through expanded cyber espionage efforts in which data held by U.S. agencies and companies is systematically accessed[40] and scientists secretly bring technical knowledge back to China.[41] However, the trade war itself was damaging to the U.S. tech industry. Apple, which operates a significant portion of its supply chain in China, suffered billions of dollars in losses while U.S.-based semiconductor companies like Qualcomm and Micron were thrown into uncertainty. In addition, the eventual deal between China and the United States failed to include many provisions sought by the tech industry (including on reciprocal market access, protecting cross-border data flows, and withdrawal of Chinese subsidies) while the commitments it did include (ending the practice of forcing U.S. companies to transfer technology as a condition of market entry and improving processes for combatting online patent and copyright infringement) were met with skepticism that they would be enforceable.

The U.S. infotech sector, especially the semiconductor industry, was then shaken by U.S. efforts to curb Huawei, the global leader in 5G equipment and technology.[42] The Chinese company was added to the Department of Commerce's Entity List, prohibiting U.S. companies from selling Huawei components without explicit government approval, in an effort to starve the firm of commercially available semiconductor chips. This government offensive against Huawei in both the American and European markets required some offsetting measures to support U.S. semiconductor equipment makers, manufacturers, and software designers. That has not yet been forthcoming.

The State Department more recently introduced a "Clean Network" initiative to eliminate the Chinese firms from the networks of the U.S. and its and attempted to force the ban of Chinese-owned apps WeChat and TikTok from the Apple and Google app

39 Alexandra Stevenson, "Facebook Admits It Was Used to Incite Violence in Myanmar," New York Times, November 6, 2018. See also Alexandra Stevenson, "Soldiers in Facebook's War on Fake News Are Feeling Overrun," New York Times, October 9, 2018.

40 Sean O'Kane, "Chinese Hackers Charged with Stealing Data From NASA, IBM, and Others," The Verge, December 20, 2018.

41 Christopher Wray, Remarks: The Threat Posed by the Chinese Government and the Chinese Communist Party to the Economic and National Security of the United States, Federal Bureau of Investigations, July 7, 2020.

42 Laurens Cerulus, "Trump and Friends: Where European Countries Come Down on Huawei," Politico, May 26, 2020.

stores. These "trade war" skirmishes again could have been part of a coordinated and coherent effort to put the U.S.-Chinese economic relationship on a fair plane. However, a failure of advocacy by the United States government, and the administration's opaque justifications give provided an opening for Chinese accusations of protectionism and have resulted in judicial injunctions.[43]

Meanwhile, China, which has created a system of surveillance and censorship at home, known as the Great Firewall,[44] presses for new approaches at the UN and standard-setting organizations to enable national control so governments can censor, surveil, gather intelligence, or even carry out cyberattacks. Unlike the United States—which hoped to create an open network in the 1990s and spread Internet freedom in the 2000s—China sends armies of engineers to the Institute of Electrical and Electronics Engineers, an international forum for standard-setting, to argue for its preferred solutions, while U.S. companies are outnumbered and uncoordinated. It now chairs the International Telecommunications Union, which it has already convinced to adopt new standards for surveillance and facial-recognition technologies.[45] China has been courting ITU delegates to replace the existing decentralized TCP/IP Internet architecture with an alternative, "New IP," that might ultimately place more power in the hands of state-owned mobile and telecommunications operators.[46] From both an American and global perspective, China's methods and intent should create anxiety. However, while the United States should be a safe haven for entrepreneurs and fertile territory for innovation, instead, America First policies have turned away from the United States talented workers from overseas. Meanwhile, needed investments in education have taken a backset to political battles.

Realizing the Promise of Distributed Computing and New Digital Platforms

Platform Power

As the United States failed to make decisions needed to lead on the Internet and keep its infotech edge, it simultaneously failed to make decisions needed to stave off a variety of crises—from climate to healthcare, infrastructure, and racial and economic inequality. Meanwhile, skepticism has risen about the ability of out-of-date government mechanisms to deliver the investments and services needed to solve these.

The next chapter in the infotech drama offers opportunity. Just as the mobile phone and the cloud enabled the creation of social-media platforms, changing the Internet and society with it, so AI, the IoT, and 5G are ushering in a new age of distributed computing that may have an even more profound impact.

The United States' ability to leverage emerging technology and compete with China, will require a strategy and investment. The new strategy to leverage distributed computing requires government investment in areas where the social benefits are great but in which the market might not invest adequately. The focus of these investments should be in creating digital platforms out of critical infrastructure and services. New digital platforms could enable the urgent updates to clean power, transportation, and water and sewage infrastructure. They can also help finally revitalize health and education—not by replacing or disintermediating professionals like teachers and healthcare workers but by empowering them. These digital platforms can address traditional obstacles of distribution and standardization, allowing innovation to scale quickly. With investments, the creation of new institutions and partnerships, updated rules of the road for private firms, and a national mission, the United States can achieve this.

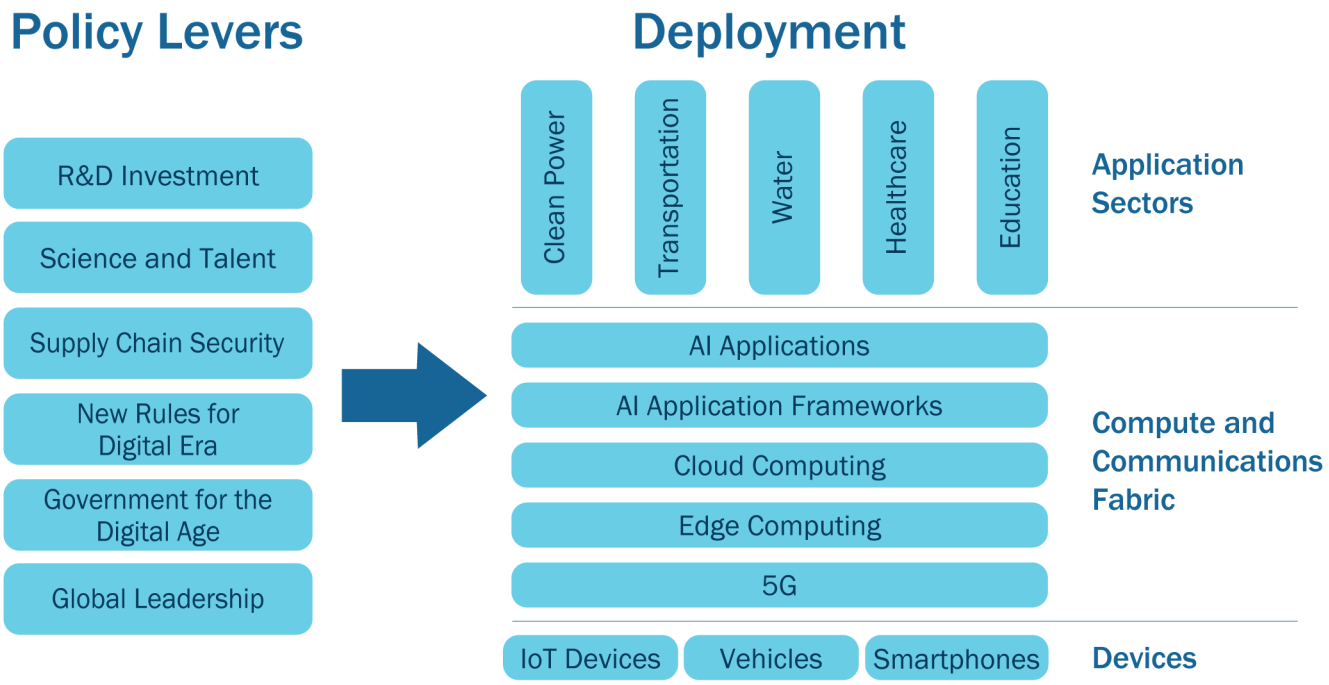
43 Chun Han Wong, "China Launches Initiative to Set Global Data-Security Rules," Wall Street Journal, September 8, 2020.

44 Graham Webster and Samm Sacks, Five Big Questions Raised by China's New Draft Cross-Border Data Rules, New America, June 13, 2019.

45 Anna Gross and Madhumita Murgia, "China Shows Its Dominance in Surveillance Technology," Financial Times, December 26, 2019.

46 Stacie Hoffmann, Dominique Lazanski and Emily Taylor, "Standardizing the Splinternet: How China's Technical Standards Could Fragment the Internet," Journal of Cyber Policy, August 29, 2020.

Leveraging Distributed Computing to Build Back Better



Below are the kinds of inspiring "moonshots" that can not only create broad-based economic growth but also demonstrate that the United States is once again able to solve big problems.

Clean Power

In power, distributed computing can advance improvements in the distribution, measurement, and mitigation of greenhouse-gas emissions from every source. Clean power will be enabled by distributed computing, which can optimize energy use in buildings by turning on lights, adjusting heating and air conditioning, and consuming power only when needed by people or industrial processes. Distributed computing can also make energy production more efficient by improving load balancing—the process by which excess power is stored during low-demand periods and released at times of increased demand. With load balancing refined to milliseconds, wind and solar power can be sold at zero marginal cost to any distribution utility, provided that the government has paid for new transmission lines between scarcely populated windy or sunny spaces and population centers.

Transportation

Transportation too should be managed by distributed computing in vehicles and adjacent to roads. In the future, goods and people will be primarily carried from place to place by autonomous electric vehicles. This transition will require modifications to the American fleet of vehicles and existing transportation infrastructure, and it will require the government to promote the proliferation of autonomous electric vehicles. In doing so, the government should create a subsidy for vehicle miles travelled electrically (and not for electric cars themselves), which would encourage light-duty trucks, taxis, ride-sharing vehicles, rental cars, and any other heavily used vehicle, that are gasoline-powered to be quickly swapped with electric upgrades. If two to five million autonomous electric vehicles were sold in the United States in each of the next three years, these could substitute for as much as half of all gas-powered

miles driven. That would mean a 50 percent reduction in greenhouse-gas emissions from automobiles, which are the single most egregious U.S. contribution to the global climate catastrophe. Beyond improvements to vehicles, distributed computing technology will also support the modernization of U.S. transportation infrastructure, including highways. "Smart" roads and highways, which integrate technology into roadways, can support sustainable energy growth by generating energy and facilitating the transition to vehicle autonomy.

Water

Distributed computing also presents the opportunity to improve the functionality of other utility networks, like the sewage and pipe systems that undergird cities. According to the American Society of Civil engineers, aging pipes and inadequate capacity leads to "the discharge of an estimated 900 billion gallons of untreated sewage each year."[47] Because of developments in distributed computing technology, it is an opportune to modernize aging sewer and water treatment infrastructure. Cities like South Bend, Indiana, for example, have integrated IoT censors into municipal sewer systems in order to monitor water levels and redirect wastewater, which according to the city, has "prevented at least 1 billion gallons of raw sewage from entering the river each year since its completion."[48]

Healthcare

The coronavirus pandemic has already provided a glimpse into the future of healthcare delivery—in which higher-quality attention can be delivered from anywhere, without the professional and the patient needing to be in the same room. The distributed computing revolution has the capacity to dramatically improve the delivery of innovative telehealth applications. By aggressively targeting these tools, the healthcare industry can ensure e-health is provided cheaply and quickly, ultimately bringing closer the ideal of healthcare as a human right. The Trump administration failed to promote test and trace as a pandemic containment measure though this represents an info-tech strategy already capable of implementation. The newly enabled combination of local data aggregation with 5G and AI offers every community the opportunity to test and trace, for example, without the expense of buying capacity from Amazon Web Services or the cost of sending data thousands of kilometers away. Local schools, hospitals, and other community centers should be able to understand precisely where the virus is, where it is going, and what can be done to stop it.

Education

In education, the pandemic has shown that there is no substitute for school and in-person teaching. Nonetheless, distributed computing can improve student outcomes. Advances in distributed computing can provide teachers with new learning tools, like mixed-reality content. Because 4G connectivity struggles with mixed-reality content, the transition to 5G will help sustain new applications like augmented reality and virtual reality. 5G connectivity will also help support an "Educational Internet of Things," which will have the effect of reducing the amount of time teachers spend on administration, enabling them to focus on instruction. Developments in artificial intelligence can transform language education by providing students with language-learning programs that calculate student's language and vocabulary weaknesses and adapt programming in real time.

Investment and Collaboration

The United States cannot realize the gains of distributed computing in the absence of a renewed innovation strategy that includes R&D investment, nurturing of science and talent, securing supply chains, updating institutions, new guardrails, and global leadership. Below is an overview of the work GMF Digital will

47 American Society of Civil Engineers, Failure to Act: The Economic Impact of Current Investment Trends in Water and Wastewater Treatment Infrastructure, 2011.

48 Environmental Resilience Institute, South Bend, Indiana Uses Smart Sewer Technology to Monitor and Manage Increased Water Levels, Indiana University.

continue in order to promote democratic use of this new technology.

R&D Investment

In terms of investment on R&D as a share of GDP, China U.S. federal R&D spending has fallen while China has been spending more.[49] The Department of Defense launched an AI Strategy in 2018,[50] the Trump administration provided approximately $1 billion in awards for the establishment of twelve new AI and quantum information science R&D institutes,[51] and R&D has grown each year. But the administration has not advocated the kinds of increases needed. In fact, it has proposed cuts to R&D spending across the government—including at critical agencies like the National Institutes of Health, the National Institute of Standards and Technology, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency[52]—as well as the elimination of the Department of Energy's ARPA-E, which makes long-term, high-risk investments in clean-energy technology.[53] To capture the benefits of distributed computing, the United States will have to reverse this trend and ensure that federal agencies have the support necessary to drive innovation.

Science and Talent

Money must also be available for investment in science, technology, engineering, and mathematics education, as well as in higher education and research facilities that will deliver innovation in the United States for years to come. The United States must also invest in workforce development. To meet the research demand that has to be created, the country also needs immigration law to encourage the recruitment of technologists from around the world. About a third of science faculty members in the United States were born in other countries. Immigrants also constitute an overwhelming share of graduate students in technical fields and account for a disproportionately large share of U.S. invention and entrepreneurship exemplifying the necessity of going offshore to recruit talent.[54]

Secure Supply Chain

In the new critical industries—including communications equipment and semiconductor manufacturing, 5G radio systems, edge and cloud computing, processor architecture, AI, and advanced energy systems—the government may need to partner and subsidize flagship firms to speed up deployment. The recent decision to promise federal funds for the Taiwanese Semiconductor Manufacturing Company to manufacture in Arizona is an interesting step. But it is critical to American security issues to guarantee that this unusual action is not undercut by increasing Chinese pressure on Taiwan's independence, both in political and business dimensions.

New Rules of the Road for the Digital Era

Through a combination of law, multi-stakeholder negotiation, and cultural suasion, there must be a change in incentives so that infotech companies exert less power and internalize what until now have been externalities born by individuals and society at large. For "Move fast and break things" to become "Move with care and help build things," the United States must get serious about updating offline protections including civil rights, privacy, consumer protection, competition, campaign finance, and cybersecurity. In addition, companies must implement practices that reduce risks to users and society—and they must

49 According to data from the National Science Foundation, federal R&D as a share of GDP has fallen from over 2.2 percent in 1964 to just 0.6 percent in 2018. Caleb Foote and Robert D. Atkinson, Federal Support for R&D Continues Its Ignominious Slide, Information Technology & Innovation Foundation, August 12, 2019.

50 U.S. Department of Defense, Summary of the 2018 Department of Defense Artificial Intelligence Strategy, 2018

51 The White House, The Trump Administration Is Investing $1 Billion in Research Institutes to Advance Industries of the Future, August 4, 2020.

52 David Malakoff and Jeffrey Mervis, "Trump's 2021 Budget Drowns Science Agencies in Red Ink, Again," Science, February 10, 2020.

53 Megan Geuss, "Trump Really Wants to Kill ARPA-E; Federal Agency Says That's Folly," ArsTechnica, March 14, 2018.

54 Caleb Watney, "America's Innovation Engine is Slowing," The Atlantic, July 19, 2020.

be subject to transparency so that they can be held accountable.

Today's infotech giants are what the computer, telephone, broadcast, cable, newspaper, advertising, and retail industries were 30 years ago—but they are all these and more rolled into the most powerful firms ever seen in the modern economy. Because of the vast range of goods and services distributed computing will produce, these firms will grow even bigger, or be replaced by even bigger and more powerful companies. Antitrust officials and policymakers have begun to contemplate structural changes, and they may consider divestitures and interconnection requirements as was done with AT&T in the 1970s and 1980s to the ultimate benefit of the infotech industry.[55]

AI poses unique challenges—already facial recognition is prohibited in various jurisdictions; predictive analytics applications in employment, housing, criminal justice, credit, and education undermine the very notion of individual agency and are vulnerable to dangerous bias. The EU has proposed a risk-based approach and the United States is looking at implementing a sectoral approach to regulation. Meanwhile, there are various multi-stakeholder efforts to integrate ethical frameworks. The United States urgently needs a strategy to ensure that AI is developed to address societal issues and with guardrails, including human explainability, accountability, and intervention. All this will require greater expertise, capacity, and agility in government as well as a greater receptivity to social responsibility on the part of tech companies.

Updating Government and Creating New Institutions for the Digital Age

The coronavirus pandemic has revealed the limits of the government's ability to deliver solutions from testing and tracing to unemployment benefit delivery.[56] To roll out these new platforms and deliver services equitably will require new institutions outside government, new systems within government, and a new willingness to collaborate across multiple disciplines. Just as purpose-built public interest, multi-stakeholder institutions were deployed to govern the early Internet, similar cooperative nonprofits should be designed to address these new challenges.

Global Leadership

The United States should join forces with allies to ensure that AI, the IoT, and 5G are rolled out and used with respect for human rights and democratic values as well as security. Likeminded countries will need to work together to promote global norms and negotiate new international agreements to counter the efforts of China and other authoritarian regimes to use these technologies to repress and dominate. The United States must serve as a global leader to ensure not only that less wealthy countries across the world can take advantage of the benefits of distributed computing but that they do so in a way that promotes these values. In doing so, the United States may need to leverage foreign aid and development resources.

Conclusion

The United States can emerge from the "pandemic-onomy" better able to tackle long-festering challenges by taking a technological leap forward. But capitalizing on the promise of distributed computing will require political and cultural willpower. It will require new institutions, new rules, new projects with allies, and new investments. And these require a commitment to common projects that the United States has been unable to muster since at least the early days of the Internet.

55 Structurally, an earned monopoly is not illegal, but the monopolists have to engage in the unnatural act of tolerating competition. When Intel was one of the most important infotech firms, at the end of the 1990s, its leader Andy Grove said that if it did not have the competitor AMD, it would have to invent a firm to play that role. It did not hurt Microsoft either to face the fact that Google beat it on numerous fronts in the early years of this century.

56 Eli Rosenberg, "Workers Are Pushed To the Brink As They Continue to Wait for Delayed Unemployment Payments," Washington Post, July 13, 2020.

However, the distributed-computing-enabled platforms discussed here offer more tangible benefits to the built environment, jobs, critical services, and the environment around the country than previous waves of innovation—and at lower cost than previous efforts to renew the United States' infrastructure. As Mark Andreessen has suggested, once the country demonstrates to itself its ability to build new solutions, it may also increase the political and cultural capital for future progress.[57] Even more so if it builds the types of mission-driven projects that economist Mariana Mazzucato has called for, such as rapidly moving the economy from carbon to clean energy, providing more equitable educational opportunity and healthcare to all, and jumpstarting a more inclusive and sustainable economy.[58]

The stresses of the coronavirus pandemic have shown that the United States society and economy are under pressure—and so too is its infrastructure. The spike in demand pushed many hospitals far beyond their capacity to meaningfully treat patients, signaling a worrying level of fragility in the healthcare sector; the wide scale pivot to work-from-home and remote educational instruction has been hampered by weaknesses in broadband and wireless infrastructure; and the inability of state and federal governments to expeditiously distribute coronavirus relief, like unemployment payments, all signal a troubling lack of meaningful state capacity. What the pandemic reveals is that innovation will be necessary to relieve the stresses the current system is under. To rise to the challenges of this era, the next administration will have to catch the wave of technological trends and set forth a constructive, optimistic, and mission-oriented approach to innovation. Doing so will allow the United States to build its future.

57 Marc Andreessen, It's Time to Build, Andreesen Horowitz, April 18, 2020.

58 Mariana Mazzucato, Mission-Oriented Innovation Policy: Challenges and Opportunities, University College London, September 2017. See also Mariana Mazzucato, The Entrepreneurial State: Debunking Public vs. Private Sector Myths, Anthem Press, 2013.

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About GMF Digital

The German Marshall Fund's Digital Innovation and Democracy Initiative (GMF Digital) works to support democracy in the digital age. GMF Digital leverages a transatlantic network of senior fellows to develop and advance strategic reforms that foster innovation, create opportunity, and advance an equitable society.

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