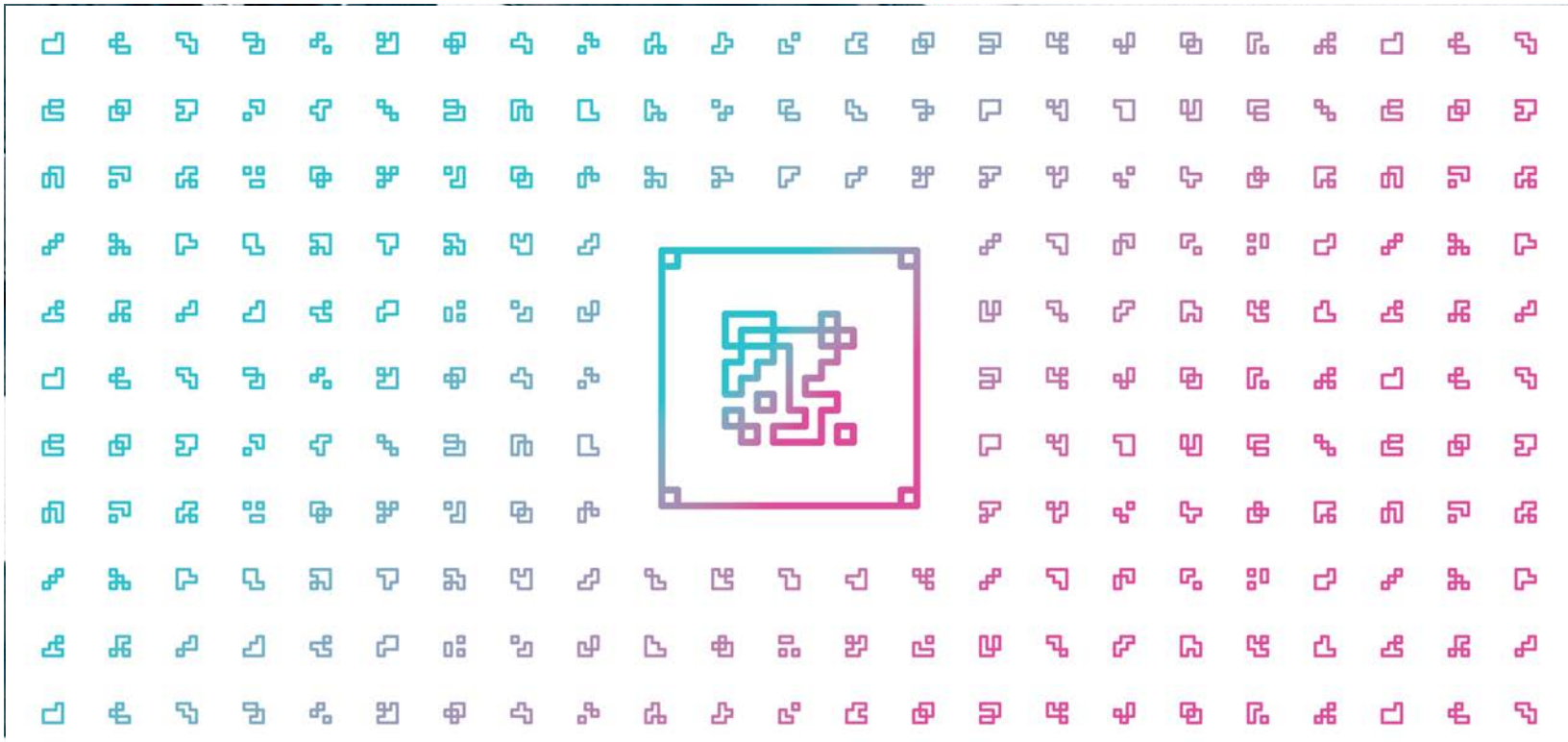

Strategic Competition in an Era of Artificial Intelligence

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By Michael C. Horowitz, Gregory C. Allen,
Elsa B. Kania, and Paul Scharre

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1152 15th Street NW
Suite 950
Washington, DC 20005

CNAS.ORG / @CNASDC
T: 202.457.9400
F: 202.457.9401

ABOUT THE AUTHORS

Gregory C. Allen is an Adjunct Fellow in the Technology and National Security Program at the Center for a New American Security (CNAS).

Michael C. Horowitz is an Adjunct Senior Fellow at CNAS and a professor of political science at the University of Pennsylvania.

Elsa Kania is an Adjunct Fellow in the Technology and National Security Program at CNAS.

Paul Scharre is a Senior Fellow and Director of the Technology and National Security Program at CNAS.

ABOUT THIS REPORT

This report is part of the Center for a New American Security's series on *Artificial Intelligence and International Security*. The series examines the potential consequences of advances in artificial intelligence for the national security community. Nearly every aspect of national security could be transformed by artificial intelligence. AI has applications for defense, intelligence, homeland security, diplomacy, surveillance, cybersecurity, information, and economic tools of statecraft. The United States must not only anticipate these developments, but act decisively to prepare for uses by competitors and take advantage of the opportunities AI presents.

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INTRODUCTION

Understanding what artificial intelligence "is" from a historical perspective is critical to assessing the ways that it will likely impact the international security environment and the future of international competition. AI is more akin to electricity or the combustion engine than a particular weapon, such as a nuclear device, or a particular platform, like a battleship. Given the extent of the disruption that analysts believe AI could cause in the global economy, it is worth thinking about the consequences of AI in the context of the industrial revolutions of the past.

Past industrial revolutions have generated significant changes in the balance of power, international competition, and international conflict. The First Industrial Revolution generated massive increases in productivity in Europe and the United States, first in Great Britain and then beyond. The consequences for the balance of power were significant. Through its technological and organizational leadership, Great Britain became the leading power in Europe, pulling away from France and Prussia. The relative edge the British gained by being the first mover in the First Industrial Revolution generated returns that fueled the continued expansion of the British empire and gave Great Britain a lead that the rest of the world would take decades to catch up to. Moreover, the disruptions to traditional family structures with the shift away from the farm, along with underlying shifts in the economy, led to social instability and ushered in an era of political instability in Europe.

The Second Industrial Revolution led to renewed international competition. The late 19th century and early 20th century featured a multipolar security environment, with Great Britain, France, Germany, and Russia among the nations competing in Europe, along with a rising Japan and United States.[1] Countries competed to control natural resources such as oil and coal and to create industries in chemicals and automobiles. No single country dominated. It was this competitive environment and uncertainty about the future that helped lay the groundwork for the escalating tensions that led to World War I.

There is less agreement among experts on the exact content of the Third Industrial Revolution, or whether one even occurred. However, something clearly changed in the late 1970s and early 1980s, when the combination of microprocessors, global production chains, and electronics produced a wave of innovation that created the internet, GPS, and a host of other technologies. This era matured during the early 1990s, a time of unique relative American power,[2] so it is not surprising that the United States led the world – economically, with companies such as Google, and militarily, with information-age weaponry.[3] Essentially, rather than leading to a power transition or intense international competition, the Third Industrial Revolution helped the United States pull further ahead.

What these industrial revolutions have in common is a shift in the character of warfare and the key implements of power. The First Industrial Revolution enabled Napoleon's *levée en masse*, or mass mobilization of the population for war. This shifted military power away from small, very professionalized militaries, such as those of Prussian leader Frederick the Great, and toward countries able to mobilize their population on a large scale.[4]

The Second Industrial Revolution fueled not only the mechanization of warfare that led to trench warfare in World War I, but a generation of capabilities that reshaped combat in the mid-20th century. Tanks, trucks, radios, and airplanes all resulted from technologies created or perfected during the Second Industrial Revolution. And it was Germany's use of these technologies that led to the invention of blitzkrieg, reshaping land warfare at the outset of World War II.

The Third Industrial Revolution, microelectronics and computing in particular, created one of the most sustainable first mover advantages in military power in modern history – the edge the United States gained due to the Second Offset strategy. Originally designed to counter the Soviet Union's numerical, conventional military supremacy in Europe, the American technological edge led to the invention of stealth and the leveraging of satellites for precision guidance. In combination, these capabilities allowed the United States to project power over the horizon in a way that it has taken decades for others to master.[5]

In these cases, a series of related questions helped determine the impact of these macro changes on the balance of power and international competition.[6] First, to what extent did the technological inventions of the period generate first mover advantages that could lock in economic and military gains for innovators? Alternatively, were innovations easy to copy, either because they could be mimicked by other countries with similar technology levels or because incentives to trade led to the diffusion of technology? In the 19th century, it was difficult to generate sustainable technological advantages. In the economic realm, for example, the development of consistent gauge railroad by the Germans, which had both economic and military consequences, was relatively easy for other countries to mimic after German success in the Franco-Prussian war.[7] In the military realm, the French invented technologies such as exploding shells only to see their inventions adopted faster, and with greater effectiveness, by the British and others.[8]

Also, the overall impact of these industrial revolutions on competition and the balance of power depended not just on the technologies themselves, but on how companies and governments decided to use those technologies. Technologies that help organizations do what they were doing before, only more efficiently, tend to be sustaining – meaning the ability of actors, whether businesses or governments, to adopt them is relatively consistent.[9]

Alternatively, technologies that force companies and governments to do things differently tend to be more disruptive. For example, in the computer industry, the shift from mainframes to personal computers introduced massive industry changes as mainframe leaders lagged in their recognition of the size of the personal computer market until after too many customers were already making the switch.[10] In the military realm, the shift from the battleship to the aircraft carrier is a classic example of the impact of technology depending not just on the technology itself, but on organizational adoption. When the British invented the aircraft carrier with the HMS *Furious*, the British Navy already led the world due to its fleet of battleships and battlecruisers. Thus, the British Navy initially saw the utility of the aircraft carrier through the lens of what they were already good at –

battleship warfare – and envisioned the aircraft carrier as providing airborne "spotters" for the battleships. Instead, it was rising powers in the form of the United States and Japan, in part due to the competitive pressure of fighting in the Pacific, that realized the true utility of the aircraft carrier was as a floating airfield. This recognition disrupted 500 years of dominance of the battleship in naval warfare in just one generation, introducing massive instability in naval warfare and the balance of power.[11]

WHAT ARE THE KEY ELEMENTS OF AI NATIONAL POWER?

The historical discussion raises the question of what the key elements of national power will look like in an era of AI. As previously described, AI is a general-purpose technology that is more analogous to the internal combustion engine or electricity than to nuclear weapons. Electricity delivered capabilities and improvements to nearly every aspect of military technology. Some of these were revolutionary, such as radio and radar, and some were merely evolutionary, such as the substitution of electrical explosive detonators for burning fuses. Like electricity, increased adoption of narrow AI technology will deliver diverse capabilities that influence economic and military power. The invention of the internal combustion engine and its use by global militaries made possessing secure access to oil a key element of national power. What will be the key elements of national power during the AI revolution? It is hard to know at this point, but there are several possibilities:

- **Owning large quantities of the right type of data –** At the moment, the most powerful machine learning techniques, such as deep learning, require large datasets to achieve high performance. Organizations with larger datasets thus have an advantage in developing superior applications. For this reason, a May 2017 *Economist* cover story argued that data had replaced oil as "The World's Most Valuable Resource."[12] The analogy between AI and oil is not perfect, however. Whereas refining technology more or less makes all oil equivalent, data is not nearly so interchangeable. The right type of data depends upon the desired application. If one seeks to develop a narrow AI system to automatically identify objects in satellite reconnaissance imagery, then having a large quantity of cell phone user data is simply useless. AI will augment the national power of those countries that are able to identify, acquire, and apply large datasets of high economic and military importance in order to develop high-performance AI systems.

- **Training, sustaining, and enabling an AI-capable talent pool –** The human capital skills required for advanced AI system development are relative rare at present. Currently, there are far more worthwhile applications of existing AI technology than there are skilled programmers to develop and implement them. As such, newly minted Ph.Ds. can often command compensation of $300,000 to $500,000 a year – or more.[13] Nations that develop education, training, and immigration policies to recruit and train top talent – from their country and from others – will have an edge on others.

- **Computing resources –** Machine learning requires large computing resources (called "compute") to train machines. This is expensive and requires access to high technology. Actors with fewer resources can utilize previously trained systems, meaning some AI technology may proliferate more easily to less capable actors. Organizations that have greater resources will have an advantage, however, in building original, cutting-edge AI systems.

- **Organizations incentivized and aligned to effectively adopt AI –** Merely developing the best advanced AI systems is not enough to secure an enduring advantage in national power. Technology in and of itself is of limited utility if companies and government organizations lack people who can use it, effective strategies for how to use it, and training to be good at using it. Leading U.S. technology companies already report that they are "remaking themselves around AI," and history suggests that organizational change is critical to success during periods of disruption.[14]

- **Public-private cooperation –** The key power players in AI up to this point are private sector companies, not governments. For governments to effectively harness AI technology for national security uses, they will need to be able to tap into the innovation occurring in private companies. China has a significant edge in public-private integration relative to the United States, with China's model of civil-military fusion a stark contrast to some of the cultural divides between the Pentagon and Silicon Valley.[15]

- **The willingness to act –** Countries may make regulatory choices to restrict their uses of AI in particular arenas, making decisions that prioritize privacy or other values over efficiency. For example, some countries are developing sophisticated regulations restricting the use of health data on grounds of privacy. While doing so may bring those nations benefits in protecting citizens' rights, there is potentially a tradeoff in limiting the use of AI applications that could be helpful. How this plays out and the implications for national power – both economic and military – are open questions.

Is AI Software or Hardware?

How technology spreads often depends on the ease that other actors have at copying that technology. As previously explained, one of the things that made stealth so hard for other actors to copy was that it was a discrete technology, and also one that only has military purposes. Software often diffuses much more easily than hardware, both because of the commercial incentives that can drive software creation and because the talent pool necessary to create new software can exist even in countries that are not generally major military producers, such as advanced economies in Asia.

The key elements of national power in AI are therefore related to the question of whether it makes sense to think about AI as software or hardware. In some ways, AI represents

software. It is not an aircraft carrier or a motor vehicle – it is not a piece of physical equipment. Especially after an algorithm is trained, AI is also implemented as a piece of software. Yet, it is far too simple to consider AI as merely software.[16]

In recent decades, computing hardware has become increasingly commoditized, such that data centers with very different data types have relatively similar hardware. Artificial intelligence technology is a noteworthy exception. Most of the most popular and powerful machine learning techniques currently in use, such as deep learning, tend to be incredibly computationally intensive.[17] Indeed, much of the current revolution in machine learning AI is a result of the availability of massive datasets and sufficiently powerful computing hardware to process them. Moreover, AI algorithms tend to favor a comparatively narrow set of mathematical computations. As such, they benefit significantly from the use of more specialized computer chips such as graphical processing units, and even more so from chips custom-designed to run AI algorithms. Many leading software technology companies have acquired or established computer chip design capabilities to improve their benefit from such custom-designed AI hardware.

Three facets stand out as critical to AI hardware at present: First, with superior hardware, the machine learning training phase of a given AI algorithm can be shrunk significantly. Training times might be shrunk from weeks or days to hours or minutes. As such, developers can run experiments and develop prototypes much faster than with traditional hardware. Second, improved hardware also reduces power consumption. The machine learning training phase requires a lot of electrical power, and electricity bills often can be a significant element of total cost. Third, some cutting-edge machine learning applications are so computationally intensive that they are not, at present, possible without access to significant computing resources. Finally, the increased computation speed and reduced power also has a significant benefit at the end-user application level. For instance, many smartphones now possess a custom chip that is optimized to run machine learning algorithms for facial recognition. Without such a custom chip, these applications would drain the battery too quickly to be useful to consumers. What is true for facial recognition on phones also will be true for object recognition AI systems in aircraft or drones.

This creates an interesting potential situation whereby hardware is required for significant advances in AI, but once it is completed AI becomes software that in some cases could diffuse more easily. This facet of AI is compounded by a culture of openness in the AI community that leads to research being widely published, and trained AI models being available to download for free online. Thus, AI complicates the traditional distinction between hardware and software when thinking about capabilities. If it takes orders of magnitude less hardware to run trained neural nets than to create them, the ability of many actors around the world to gain access to algorithms may depend in some ways on who creates those algorithms (e.g., if they are willing to export them) and how they do so. The commoditization of algorithms will become critical in influencing diffusion patterns.

THE CHARACTER OF INTERNATIONAL AI COMPETITION

The United States is only one of many players in artificial intelligence, and many nations are taking steps to ensure their competitiveness in AI.[18] Former Deputy Secretary of Defense Robert Work and former Alphabet CEO Eric Schmidt have compared the race to be the world leader in AI to the Cold War race to the moon between the United States and Soviet Union.[19]

One key difference between AI development and the space race, however, suggests that competition in the AI arena could be even more intense. The space race was fundamentally a bipolar competition – a subset of the broader Cold War. The United States and Soviet Union were the most powerful countries in the world, and the only countries capable of being even close to world leaders in space technology. Competition in AI, on the other hand, may be much more intense because it will be much more multipolar and multisector. Countries around the world want to be leaders in AI and are leveraging advanced information economies, in some ways, to try to gain an edge. While the United States and China are global leaders in AI, many other countries are investing heavily.

- **Israel** is investing heavily in AI for both military and commercial purposes.[20] As a capital-rich country with a relatively small population, Israel stands to benefit disproportionately from AI technologies.

- **Russia** is investing in AI and robotics, though concentrated more in the military arena than anywhere else. These moves illustrate that Russian investments are following Vladimir Putin's 2017 statement that "artificial intelligence is the future, not only for Russia, but for all humankind. It comes with colossal opportunities, but also threats that are difficult to predict. Whoever becomes the leader in this sphere will become the ruler of the world."[21]

- **Singapore** is leading Southeast Asia in AI investments, leveraging its role as a technology hub to attract investments.[22]

- **South Korea** is not just investing in commercial applications of AI, but using algorithm-based systems to help monitor the demilitarized zone.[23]

These investment patterns also suggest that AI, in particular, could benefit countries that are capital intensive. Given the way AI allows companies or governments to substitute labor for capital, countries that already have leading technology sectors are poised to benefit. Thus, AI systems may provide the largest relative edge to those countries like Israel and Singapore that could benefit most from technological change that could usher in a more labor-light economy.

To be fair, the United States and China, and businesses in the United States and China, have some advantages that could help keep them ahead. The United States benefits from having the world's best university system and the most advanced AI researchers in academia.[24] Even though the spillovers to the commercial and military realm can be slow to develop,

this helps guarantee a baseline of U.S. technological leadership. U.S. companies such as Google also already have massive quantities of data, making it easier for them to generate machine learning algorithms than competitors starting from scratch. China similarly has access to vast swaths of data, especially because state control of the internet means China can harvest data for the purposes of training algorithms in a much more systematic way than the United States.

Education policy increasingly will become a national security issue in an era of artificial intelligence. The trend in both secondary and college environments is to favor science, technology, engineering, and mathematics (STEM) over the humanities, and that trend is likely to accelerate in an era of AI. Nations with strong cadre of scientists, mathematicians, and engineers will be better prepared to compete on the global stage, advancing the frontiers of AI and designing new AI applications. There also may be an opportunity for trade schools to revolutionize themselves by focusing more on coding and other skilled professions that could become more like "trades" in an era of AI. Nontechnical professionals also will be needed to manage many of the disruptions caused by AI; across many professions, human skills that are hard for machines to replicate, such as interpersonal interaction, will be valued. The engine of AI-driven growth will be STEM talent, however, and the high salaries commanded by top AI researchers – on par with professional athletes – speak to the current scarcity of talent.[25] Ironically, in an era that is likely to broadly shift the labor-capital balance toward capital, a decisive factor in which actors emerge on top may be human capital. Education policy could become even more important and controversial if major workplace dislocation occurs, and especially if other countries such as China and India are perceived as starting to pull ahead of the United States.

The competition for AI leadership will have significant consequences for international politics. From a military perspective, AI leadership could be increasingly necessary for the creation and deployment of effective military forces. From an economic perspective, which of course has military implications, AI leadership could be critical for overall economic leadership, meaning the countries that lead in AI will have a leg up in the global economy. The sharper the competition, though, the greater the need to also think about the potential for a race to the bottom in AI safety. As countries and companies competitively create AI applications, especially if they believe that there are large advantages to being first movers, there is a risk that countries may put aside the safety and reliability concerns outlined in a previous section due to the desire to be first. Such a race to the bottom would escalate the potential for AI-driven accidents, both in the commercial and military sectors.

CURRENT U.S. STRATEGY

Unlike China, the United States does not currently have a structured national strategy for how to approach artificial intelligence. To some extent, the lack of a U.S. national strategy for AI reflects the difference between America's democracy and China's more autocratic regime. It can be complicated to reconcile free market principles with structured investment strategies for complex areas that cover both military and civilian arenas.

During the last year of the Obama administration, the White House released several papers designed to move the United States toward a more coherent approach to artificial intelligence. Covering issues ranging from regulation to innovation to bias, these reports drove a series of conversations between scientists and government officials. Some of the authors of this report have argued that China's AI strategy reflects the key principles from the Obama administration report – now it is China adopting them, instead of the United States.[26]

The Trump administration is now beginning to consider how to approach AI. In the defense sector, the U.S. Department of Defense, given warnings from the Defense Innovation Advisory Board and the Defense Science Board, appears interested in more systematically determining how to integrate artificial intelligence. At the national government level, however, the Trump administration initially argued that they are leveraging resources behind the scenes to support U.S. innovation in AI.[27] Recently, however, the Trump administration held an AI summit, designated AI a research and development priority, and announced plans to study how to ensure the United States remains the world leader in AI.[28] In the conclusion of this report, we discuss some potential options. While not a panacea, a formal national AI strategy could mobilize policy change to more optimally take advantage of the opportunities presented by AI. At the least, a national strategy would be a symbol of U.S. commitment to AI innovation, which could play a role in ensuring the United States remains an AI leader.

Recently, House Representative Elise Stefanik (R, N.Y.) introduced legislation designed to move toward a more coherent U.S. national strategy for AI. Her legislation would create a "commission to review advances in AI, identify the nation's AI needs and make recommendations to organize the federal government for the threat."[29] As this report shows, the issue for the U.S. government is not simply a military or economic challenge. Any successful AI strategy has to involve multiple policy areas, including:

- Nurturing initial AI investments
- Building a talent pool for future AI technology development
- Establishing industry leadership
- Determining economic policy options for displaced workers
- Considering government use both inside and outside the military
- Evaluating ethical and moral issues about using AI
- Confronting the challenge of bias in algorithms

Thus, any successful AI policy would intersect with a litany of policy areas, including trade, education, welfare, military, and others. The gap between the creation of technology and

the successful use of technology, both inside and outside of government, is the best argument for a national approach to AI. Market forces in the United States may be enough to generate the invention of technologies that could keep particular businesses on the cutting edge. But creating cutting-edge technologies is no guarantee that government actors will implement them to be more efficient and effective, or that governments will design regulations to ensure safe usage. For example, government regulation of autonomous vehicles undoubtedly will be essential to their effective adoption on the roadways of the United States. A national approach is critical for coordination and for mobilizing key government agencies to make the necessary organizational changes to take advantage of AI in a way that is consistent with American values.

IMPACT ON THE BALANCE OF POWER

Forecasting is always difficult, especially when thinking about complex and interactive environments like the global economy and the international system. National power derives in many ways from the intersection of economic power and military power, though over time a strong economic base is necessary to sustain military advantages. As a critical enabler of future economic success, leadership in AI thus is likely to be critical to the macro balance of power and international competition. Leadership in this context means several things, including private sector and public sector leadership. First, countries with companies that lead in specific uses of AI will have significant economic advantages, particularly for heavy compute algorithms that are difficult for others to replicate. Those kinds of first mover advantages, where intellectual property can lock in future economic success, can help ensure economic leadership.

A lot will depend on the extent to which inventions in AI are relatively easy to replicate. This, in turn, will depend in part on the degree of similarity between particularly useful military applications of AI and commercial applications. The more applications of AI in the military realm are things such as image recognition, which has clear commercial applicability, the higher the incentives for companies around the world to invent similar technology, and the faster capabilities are likely to spread. The more applications of AI in the military realm are things such as battle management, which is more unique to militaries, the easier it will be to shield them from competitors for longer periods of time, generating more sustainable first mover advantages.[30]

Second, the impact of AI on national economic and military power is likely to depend as much on how governments decide to adopt and use narrow AI capabilities as on the technology itself. It is rare for countries to get sustainable advantages in raw technology categories, or for the technology in and of itself to be decisive. Stealth, an outgrowth of the second offset, might be one of the few examples of a technology that was so "excludable" from others that the United States gained a generation-long advantage. This is particularly true for technological innovations such as the combustion engine or electricity, e.g., massive enabling technologies, as opposed to specific military technologies.

Thus, the countries most likely to succeed over time in a world of AI revolution are those that experience economic success due to AI and are able to apply AI capabilities to their

militaries in ways that optimize their abilities to fight and win wars – even if those applications are organizationally and bureaucratically disruptive. More broadly, nations that rise ahead in the AI revolution will be those that not only harness the advantages of AI, but also have an effective plan for managing the societal disruption that it will bring.

ARTIFICIAL INTELLIGENCE COUNTRY CASE STUDIES

At present, the United States is a global leader in AI, but U.S. primacy in innovation is confronting challengers. Increasingly, nations worldwide are mobilizing policy support for advances in AI technologies and applications, recognizing its importance to future economic dynamism and military capabilities. Although experts like Kai-Fu Lee predict the emergence of a "duopoly" between the U.S. and China as AI superpowers,[31] there will be opportunities for a range of contenders to take advantage of AI to enhance their national power. Below are case studies on the state of AI in three nations – China, India, and Russia.

China

China has rapidly emerged as a powerhouse in artificial intelligence, seeking to become "the world's premier AI innovation center."[32] In its "rise" in AI, the active efforts and advances of major technology companies have predated more recent policy support. China's quest to "lead the world" in AI, while building up an AI industry of 1 trillion RMB (about $150 billion) by 2030, will involve an ambitious national agenda for this strategic technology, as articulated in the New Generation AI Development Plan (新一代人工智能发展规划), released in July 2017.[33] Although the future trajectory of China's AI revolution remains to be seen, China is rapidly building momentum to harness state support to leverage the dynamism of commercial enterprises in a new model of innovation, while also taking advantage of critical synergies with national defense applications through a national strategy of military-civil fusion (军民融合).

It is striking just how rapidly AI has emerged as a high-level priority for Chinese leaders. In many respects, the private sector has pioneered China's AI revolution to date. Baidu, in particular, has actively pursued an 'AI first' agenda since launching its Institute for Deep Learning in 2013 and establishing its Silicon Valley AI Lab in 2014. The Chinese government has only more recently elevated AI as a national 'megaproject,' in the tradition of Chinese techno-nationalism. AlphaGo's triumph over Lee Sedol in March 2016 was a catalyst for these recent plans, acting as a "Sputnik moment" of sorts for China, including through raising concerns among Chinese military leaders about the potential disruption of AI in command and decision-making.[34] Against the backdrop of U.S. plans and reports released in mid- and late 2016 under the Obama administration, AlphaGo was seen as another indication of U.S. advances in disruptive technologies that could place China at a distinct disadvantage.

Since its release, China's national AI plan has acted as an impetus for new energy across China's science and technology bureaucracies and even to local governments nationwide.

In November 2017, the Ministry of Science and Technology convened a high-level meeting that marked the official launch of the plan, establishing an office responsible for its implementation. This will be a whole-of-government endeavor involving more than 15 different entities.[35] In December 2017, the Three-Year Action Plan to Promote the Development of New-Generation Artificial Intelligence Industry (促进新一代人工智能产业发展三年行动计划) (2018-2020) called for China to achieve "major breakthroughs in a series of landmark AI products" and "establish international competitive advantage" by 2020.[36] In parallel to these efforts at the national level, a growing number of cities and provinces throughout China, including Beijing, Shanghai, and Tianjin, have started to develop and release their own plans and policies for AI.[37] For instance, Beijing plans to build a 13.8 billion RMB ($2.12 billion) AI development park that could host up to 400 AI enterprises.[38] It remains to be seen whether these disparate initiatives prove effective in creating dynamic innovation ecosystems.

As China throws state support and resources behind AI development, major Chinese technology companies will remain integral players in this endeavor. Several leading Chinese AI companies, acting as the 'national team,' will undertake the development of new "open innovation platforms" in AI.[39] Baidu is responsible for autonomous vehicles, Alibaba Cloud (Aliyun) for smart cities, Tencent for medical imaging, and iFlytek for smart voice. Notably, Baidu is leading China's National Engineering Laboratory for Deep Learning Technologies (深度学习技术国家工程实验室), established in March 2017, which will pursue next-generation research in deep learning.[40] Baidu will also contribute to the National Engineering Laboratory for Brain-Inspired Intelligence Technology and Applications (类脑智能技术及应用国家工程实验室), established in May 2017, which aims to develop AI technologies that learn from the mechanisms of the human brain and to promote brain-inspired neural chips and intelligent robotics.[41]

The direct involvement of these commercial enterprises in national laboratories that may pursue dual-use technologies and applications reflects their deep entanglement with the overall agenda of the party-state. Increasingly, China's "party-corporate complex" is deepening and a national strategy of military-civil fusion (军民融合) is advancing.[42] Indeed, the Chinese People's Liberation Army (PLA) recognizes and seeks to take advantage of the disruptive military potential of these technologies.[43] According to Lieutenant General Liu Guozhi (刘国治), director of the Central Military Commission's Science and Technology Commission, AI "will accelerate the process of military transformation, causing fundamental changes to military units' programming, operational styles, equipment systems, and models of combat power generation, ultimately leading to a profound military revolution."[44] He warns, "Facing disruptive technology, [we] must … seize the opportunity to make a sharp turn to surpass (弯道超车); if you don't disrupt, you'll be disrupted!"[45]

The PLA aspires to leverage the AI revolution to leapfrog the United States and achieve a decisive advantage relative to regional rivals in the process. The Central Military Commission Joint Staff Department has called for the PLA to use the "tremendous

potential" of AI in planning, decision support, and operational command.[46] In addition, the Joint Staff Department has called for the application of big data, cloud computing, AI, and other cutting-edge technologies in the construction of a joint operations command system.[47] Building upon its ongoing agenda of informatization (信息化), the PLA is seeking to advance "intelligentization" (智能化) as the next stage in its modernization and to harness AI as a force multiplier for its future combat capabilities. China is advancing in research and development for a range of military applications of AI, including intelligent and autonomous unmanned systems; AI-enabled data fusion, information processing, and intelligence analysis; war-gaming, simulation, and training; defense, offense, and command in information warfare; and AI-enabled support to command and decision-making, among others.[48]

Going forward, China likely will remain at the forefront of advances in AI, though uncertainties remain about its future trajectory and prospects to realize its ambitions. Certainly, AI could transform society and the economy in China in positive ways, from education to healthcare. If the current momentum and investment translates into reality, it may help China leapfrog the rest of the world in many of these applications. For instance, plans for smart cities, such as the Xiong'an New Area outside of Beijing, could result in futuristic metropolises in which 5G, AI, big data, the Internet of Things, and cloud computing are pervasively integrated into urban development to enhance energy, transport, and overall quality of life. However, at the same time, it can be difficult to disentangle this expansive AI agenda from the Chinese Communist Party's priorities and attempts to assure state security by bolstering its capacity for social control. Indeed, the creation of smart cities is linked to and will enhance the state's "social management" capabilities.[49] Unsurprisingly, the PLA also seeks to take advantage of rapid advances in AI to pursue a range of military applications that might enhance its future capabilities. Put simply, China is attempting to implement a transformative trajectory in AI.

India

India is also starting to recognize the significance of AI and prioritize it accordingly. At its current stage of development, India could be highly vulnerable to the disruptive impact of automation, but AI may also have the potential to add $957 billion to India's economy in 2035, by one estimate.[50] India could possess the requisite human capital and foundational digital economy to emerge as a major player in future AI development, as evidenced by a growing number of AI start-ups.[51] Against the backdrop of China's AI ambitions, there have been calls and initial momentum for India to develop its own strategy to take full advantage of AI.[52] According to a government think-tank, priorities in India's future AI strategy will include health care, agriculture, education, smart cities and infrastructure, and smart mobility and transportation.[53] It remains to be seen, however, whether India will develop and successfully implement a national strategy in AI, while overcoming some major obstacles.

The Indian government is starting to explore policy measures that might enable the emergence of a robust AI ecosystem. In August 2017, India's Commerce Ministry

established the Task Force on AI for India's Economic Transformation.[54] Its members include experts, academics, researchers, and industry leaders. The task force will formulate "concrete and implementable" recommendations for Indian institutions to implement going forward. In particular, its mission includes the pursuit of AI development across a range of domains and applications, including fintech, education, health care, and agriculture.[55] Reportedly, its main focus is acting as a "key enabler" for AI development, supporting entrepreneurship, and advancing AI development for national security.[56]

In addition, India is starting to evaluate and progress in potential applications of AI in defense. Under India's Defence Research and Development Organization, the Center for Artificial Intelligence and Robotics (CAIR) dates back to 1986 and today focuses on AI, robotics, and command and control, among other defense research and development priorities.[57] To date, CAIR has pursued developments in these areas that include a robot sentry, autonomous navigation system, and an autonomous search robot, among others.[58] Notably, in February 2018 India's Department of Defence Production established a new task force to study military applications of AI, with an order that emphasized, "While [AI] can fuel technology driven economic growth, it also has potential to provide military superiority."[59] In addition, in January 2018 there was an announcement that India and Japan plan to collaborate to introduce AI and robotics in the defense sector, building upon existing strategic cooperation that has intensified in response to concerns over potential threats from China.[60] At the time, a national security adviser to Prime Minister Shinzo Abe highlighted, "You should expect to see increased bilateral cooperation between us to develop unmanned ground vehicles (UGV) and robotics."[61]

Going forward, India will confront major challenges in AI development. At present, India lacks adequate expertise and human capital, particularly relative to the U.S. and China.[62] There are concerns that current educational opportunities are inadequate, including because the thousands of engineering colleges in India do not have adequate curricula to produce a robust talent pipeline of AI experts.[63] At present, the Indian government is working to create new professional programs that allow students to earn certifications in AI.[64] At the same time, India has current shortfalls in the availability of data and funding. There are billions of dollars invested in AI in the United States and China, but Indian start-ups raised less than $100 million between 2014 and 2017 and often lack access to datasets of sufficient size as well.[65] Nonetheless, if able to overcome these challenges, India could take advantage of the opportunities that AI may bring.

Russia

Although Russia may lack the dynamism of U.S. and Chinese innovation ecosystems, the efforts of the Russian defense industry to advance military applications of AI and robotics could result in real impact on today's and future battlefields. Current levels of investment within Russia, estimated at 700 million rubles ($12.5 million), are quite low relative to private sector and governmental spending in the United States, China, and even India, though private sector investment is projected to increase to a level of 28 billion rubles ($500 million) by 2020.[66] Russian President Vladimir Putin's dramatic and oft-quoted

remark, "Artificial intelligence is the future, not only for Russia but for all humankind. ... Whoever becomes the leader in this sphere will become the ruler of the world," seems to have been an impetus and accelerant for indigenous development of new capabilities that seek to leverage this disruptive technology.[67]

Whereas AI development in the United States and China has advanced through dynamic commercial enterprises, in Russia the Ministry of Defense, along with elements of defense industry, appears to be taking the lead.[68] For instance, Russia's Foundation for Advanced Studies, established in 2012 as a Russian response to DARPA, will be leading a range of new projects involving AI systems, including for image recognition and imitation of the human thought process.[69] Given Russia's recent attempts at influence and information warfare, it is also unsurprising that Russian researchers are looking to leverage AI to enhance these tactics and techniques to further "manipulat[e] the information environment," which could include the use of fake data to intensify confusion.[70] Certain Russian information technology companies, such as Yandex, Mail.ru Group, and a number of AI start-ups, are also investing in commercial applications of AI.[71] Reportedly, Russia follows the United States, China, and India to rank fourth in the number of people using Kaggle, a crowdsourcing platform for AI researchers.[72]

Beyond research efforts, Russia is actively and openly developing weapons systems that will incorporate AI. For instance, Russia's Kalashnikov reportedly has been testing a combat module equipped with a machine gun that uses "neural network technologies that enable it to identify targets and make decisions."[73] The robust Russian development of military robotics and unmanned ground vehicles may focus on increasing their autonomy.[74] There also are claims that the Armata T-14 "super tank" has an autonomous turret, and that future advances could result in the fielding of fully autonomous tanks.[75] Meanwhile, Russia's Tactical Missiles Corporation is already engaged in work on "AI-guided missiles" with the capability to determine their own direction.[76] Russian General Viktor Bondarev, who acts as commander-in-chief of the Russian Air Force, has confirmed the initial development of AI-guided missiles.[77] Although Russian efforts in swarm intelligence don't appear to be as advanced as those of the United States and China, the CEO of Russia's Kronstadt Group has predicted that "swarms of drones" will "undoubtedly" take to the skies in future conflicts.[78] At the same time, Russia may be attempting to develop an autonomous underwater vehicle (AUV), called Status-6, as a nuclear delivery vehicle.[79]

Looking forward, the Russian government's approach to the legal and ethical issues that will arise with the development of military applications of AI and even lethal autonomous weapons remains questionable. For instance, its statement to the UN Group of Government Experts on Lethal Autonomous Weapons Systems declared, "Political declarations, codes of conduct and other measures fall far short of what is needed to address the multiple and serious ethical, legal, operational, technical challenges raised by these weapons systems."[80] To date, according to expert analyst Samuel Bendett, there appears to be consensus that humans will be kept in the loop, at least for the near future.[81] However, it remains to be seen how Russia's approach may evolve as the underlying technologies advance. For instance, Viktor Bondarev, chairman of the Federation Council's Defense and

Security Committee, has declared that AI could someday "replace a soldier on the battlefield and a pilot in an aircraft cockpit."[82]

CONCLUSION AND RECOMMENDATIONS

Whether AI systems will trigger a new industrial revolution or simply be a significant new enabling technology that helps shape economies and global politics, managing the creation and use of AI technology is essential. At present, despite assessments done in 2015 and 2016 by the Obama administration, the United States lacks an effective, whole-of-government AI strategy.

The stakes in the race for AI leadership are high. Given the breadth of AI, with its ability to influence defense, diplomacy, intelligence, economic competitiveness, social stability, and the information environment, falling behind in AI development and implementation would present a risk for U.S. global economic and military leadership. The United States may very well be in a new space race, but unlike China, the United States has not yet experienced a true "Sputnik moment" from the perspective of the broader public and policymakers. The act of launching a person into space by the Soviet Union in 1958 was so audacious – and public – that it demanded a response. One risk for a country like the United States is that the "Sputnik moment" in AI happens too late – when China already has a decisive edge and uses AI in a way that undermines U.S. economic or military power.

Yet leadership in AI will not be just about the technology itself, but about how societies manage the technology. Moreover, unlike in the space race, the key technologies are likely to be built anyway for commercial reasons, and private sector companies are the leaders in technological invention, not governments. Bridging the gap between the creation of AI technology and its effective usage both inside and outside government will be an enormous challenge. We still do not know whether it will be most important in the age of AI to be first in the creation of a technology, or to be first in figuring out how to use a technology. History suggests that the latter will be essential to global power, both military and economic. Thus, strategies for leveraging the technology will become essential.

The task of policymaking in the AI arena is complicated by the vulnerabilities of narrow AI methods at present, both due to the potentially deliberate actions of adversaries and due to some inherent uncertainty about AI systems. The intersection with cyber and information security, in particular, will require a great deal of coordination to ensure that AI systems are not just advanced but safe to use.

During the tail end of the Obama administration, the White House Office of Science and Technology Policy (OSTP) led a broad interagency process to begin to grapple with many of the challenges posed by the AI revolution. The outcome of this effort was a *National Artificial Intelligence Research and Development Plan* (October 2016), a document on *Preparing for the Future of Artificial Intelligence* (October 2016), and a document on *Artificial Intelligence, Automation, and the Economy* (December 2016). These documents provided an initial toehold on the challenges to come, but sustained effort across the U.S. government, in partnership with the private sector, is needed to manage the disruptions

and take advantage of the opportunities posed by the AI revolution. The White House OSTP should lead a renewed interagency effort, in coordination with Congress and the private sector, to take action on the items listed below.

Similarly, members of Congress have shown tremendous interest and leadership on AI by creating an AI caucus, sponsoring hearings, and drafting legislation on a National Commission on Artificial Intelligence. In coordination with the executive branch and private sector, Congress should identify priorities for AI in national security, authorize and fund government AI initiatives, establish reporting requirements for agencies, and pass appropriate regulations to advance the priority areas below.

This report recommends that the U.S. government, in partnership with the private sector, undertake a broad series of actions to prepare for the challenges posed by advances in AI.

- **Strategy –** In order to manage the challenges ahead, the United States needs a national AI strategy to take advantage of the benefits of AI while mitigating its disruptive effects.

- **Research & Development (R&D) –** The United States should build on the existing National AI R&D plan, refreshing the plan based on new AI developments, establishing metrics and processes for effective execution, and developing a national security AI R&D plan for specific investments in national security areas, including AI safety.

- **Funding –** The U.S. government should increase its investment for AI research with unique national security applications that are unlikely to be funded by the private sector. To support this effort, the Office of Management and Budget should develop cross-cutting metrics to evaluate AI funding levels, and the effectiveness of that funding, across agencies. Additionally, the government should develop a clearinghouse for the funding of AI priorities that coordinates across departments in a way that allows different departments to take advantage of R&D occurring in other arenas.

- **Acquisitions –** The United States should expand upon nascent efforts within different parts of the government, such as DoD's Project Maven, and establish a whole-of-government initiative to harness and rapidly integrate AI tools within government operations. This should include breaking down barriers to innovation to make it easier for the government to rapidly integrate emerging technologies.

- **Safety –** The U.S. government should increase its investment in AI safety to improve the prospects for building robust, reliable, and explainable AI systems in national security settings. Because many current AI approaches have significant vulnerabilities, the United States should include safety and robustness against adversarial manipulation as a key element of its effort to incorporate AI technology, and employ "red teams" to test AI tools before they are deployed.

- **Metrics –** The U.S. government should establish a comprehensive program to measure, assess, and track progress in AI capabilities internationally and the diffusion of AI across the international system to various actors. This would reduce the risk of strategic surprise and help policymakers prepare for potential malicious uses of AI by state and non-state actors.

- **Education –** The development of appropriate human capital will be critical to economic and military leadership in an era of artificial intelligence. Investing in STEM education will continue to be a U.S. national security priority. Investing in trade schools and other opportunities to generate coders and skilled professionals inside the United States could aid in ensuring the United States remains a global AI leader. More broadly, policymakers must help American workers prepare for the transition to an AI-driven economy, reorienting education toward skills that are complementary to, and not competitive with, automation.

- **Immigration –** The U.S. government should adopt immigration policies that incentivize top-tier AI talent globally to come to the United States and stay, contributing to the pool of AI talent in the United States and bolstering overall U.S. economic competitiveness.

- **Data –** The United States should develop appropriate regulations governing the collection, storage, and use of data for AI purposes. Data is the fuel that will help power advanced narrow AI systems. Data regulations must balance a range of competing interests: individual privacy and protection, economic competitiveness, incentivizing innovation, and national advantage. This may be more challenging for a democracy like the United States, which has concerns about individual rights and privacy, than more autocratic countries such as China.

- **Competition –** The United States should take appropriate reforms to protect critical national advantages in AI, including protecting intellectual property from theft, restricting the export of sensitive technologies, and undertaking legislative reform of the Committee on Foreign Investment in the United States.

- **Norms –** The United States should take the lead in developing norms and principles internationally for the safe and responsible use of AI in national security settings, in partnership with like-minded allies.

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