Deciphering China's AI Dream

The context, components, capabilities, and consequences of China's strategy to lead the world in AI

Jeffrey Ding*

Centre for the Governance of AI,

Future of Humanity Institute, University of Oxford

March 2018

*Address correspondence to jeffrey.ding@magd.ox.ac.uk.

For comments and input, I thank: Miles Brundage, Allan Dafoe, Eric Drexler, Sophie-Charlotte Fisher, Carrick Flynn, Ben Garfinkel, Jimmy Goodrich, Chelsea Guo, Elsa Kania, Jade Leung, Jared Milfred, Luke Muehlhauser, Brian Tse, Helen Toner, and Baobao Zhang. A special thanks goes to Danit Gal for feedback that inspired me to rewrite significant portions of the report, Roxanne Heston for her generous help in improving the structure of the report, and Laura Pomarius for formatting and production assistance.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Marked by the State Council's release of a national strategy for AI development in July 2017, China's pursuit of AI has, arguably, been "the story" of the past year. Deciphering this story requires an understanding of the messy combination of two subjects, China and AI, both of which are already difficult enough to comprehend on their own. Toward that end, I outline the key features of China's strategy to lead the world in AI and attempt to address a few misconceptions about China's AI dream. Building off of the excellent reporting and analysis of others on China's AI development, this report also draws on my translations of Chinese texts on AI policy, a compilation of metrics on China's AI capabilities vis-à-vis other countries, and conversations with those who have consulted with Chinese companies and institutions involved in shaping the AI scene.

The report is organized in four parts: (1) **Context** - I place China's AI strategy in the context of its past science and technology plans, as well as other countries' AI plans; (2) **Components** - I relate the key features of China's AI strategy to the drivers of AI development (e.g. data, talented scientists); (3) **Capabilities** - I assess China's current AI capabilities by constructing a novel index to measure a country's AI potential; (4) **Consequences** - I highlight the potential implications of China's AI dream for issues of AI safety, national security, economic development, and social governance. In each of these four parts, I dispel a common misconception about China's approach to AI (Table 1). Then, using the deconstruction of these myths as a starting point, I derive my own findings. What follows is a summary of the key findings in each section.

Table 1: Demystifying China's AI Dream

Myths	Reality
1. The State Council's AI plan was the starting point of China's AI planning	The plan both formalizes and definitively signals a national-level focus on AI, but local governments and companies were already engaging in subnational planning on AI. Additionally, crucial elements of the State Council's AI plan are rooted in past science and technology plans.
2. China's approach to AI is defined by its top-down and monolithic nature	While the central government plays an important guiding role, bureaucratic agencies, private companies, academic labs, and subnational governments are all pursuing their own interests to stake out their claims to China's AI dream.
3. China is winning the AI arms race	China may define "winning" differently than the U.S., and, according to my AI Potential Index (AIPI), China's AI capabilities are about half of those of America.
4. There is little to no discussion of issues of AI ethics and safety in China	Substantive discussions about AI safety and ethics are emerging in China. A new book authored by Tencent's Research Institute contains chapters that are relatively proactive in calling for stronger awareness of AI safety issues. No consensus exists on the endpoints of AI development.

The State Council's AI plan is not the be-all and end-all of China's AI strategy. In the "Context" section, this report benchmarks both the plan and China's overall AI approach with regard to China's current AI capabilities and the positions of other countries on AI. Analyzing China's AI development in these two contexts gives the following conclusions:

- In addition to increased policy support for AI development in the past two years, the State Council plan's targets for the growth of the AI industry confirm China's high expectations for AI development. The 2020 benchmark for the core AI industry's gross output (RMB 150 billion) would represent a tenfold increase of the AI industry in the next three years.[1]
- The plan clearly outlines China's ambition to lead the world in AI. Additionally, Chinese AI experts and decision-makers are keenly aware of the AI strategies and capabilities of other countries, including the United States, the EU, Japan, and the United Kingdom. There is evidence that China focuses on U.S. AI strategy, in particular, as a reference point for its own approach. One reasonable hypothesis is that China views AI strategy as a bilateral competition to some extent; another is that the U.S. can credibly shape China's approach in some respects.

In the second section on "Components," I link the key features of China's AI strategy – those consistent with other science and technology plans as well as those that differ – to four factors that drive the overall development of AI: (1) hardware in the form of chips for training and executing AI algorithms, (2) data as an input for AI algorithms, (3) research and algorithm development, and (4) the commercial AI ecosystem. Structuring the analysis by driver helps unpack how different features of China's AI strategy are put in practice in the following ways:

- There are important similarities and differences between China's approach to AI development and its past efforts to guide scientific and technological innovation in other areas. Key consistencies include: a strong degree of state support and intervention, transfer of both technology and talent, and investment in long-term, whole-of-society measures. Significant differences are rooted in two factors: AI's "omni-use" potential means the breadth of actors involved is much wider than for other technologies, and as a result, internationally-facing, private tech giants and vigorous startups are leading players in driving innovation in AI.
- China is adopting a "catch-up" approach in the hardware necessary to train and execute AI algorithms. It has supported "national champions" with substantial funding, encouraged domestic companies to acquire chip technology through overseas deals, and made long-term bets on supercomputing facilities. Importantly, established tech companies like Baidu and startups like Cambricorn are designing chips specifically for use by AI algorithms.
- Access to large quantities of data is an important driver for AI systems. China's data protectionism favors Chinese AI companies in accessing data from China's large domestic market but it also detracts from cross-border pooling of data. Also, the common view that China's AI development will benefit from relatively lax privacy protections on user data may no longer hold true with the promulgation of a new data protection law.
- China is actively recruiting and cultivating talented researchers to develop AI algorithms, another

1 This calculation takes the State Council's targets and compares them to a iiMedia Research Group report's estimate of the scale of China's industry in 2017. I assume that the iiMedia Research Group's estimate is close to what the State Council views as ground truth, but the State Council may be working off of a different estimate for the current gross output of the core AI industry (iiMedia, 2017).

essential factor in AI innovations. The State Council's AI plan outlines a two-pronged "gathering" and "training" approach. National-level and local-level "talent programs" are gathering AI researchers to work in China, while China's tech giants have set up their own overseas AI institutes to recruit foreign talent. The training plank takes a long-term view to growing AI talent through constructing an AI academic discipline and creating pilot AI institutes.

- Lastly, the Chinese government is starting to take a more active role in funding AI ventures, helping grow the fourth driver of AI development – the commercial AI ecosystem. Disbursing funds through "government guidance funds" (GGF) set up by local governments and state-owned companies, the government has invested more than USD 1 billion on domestic startups, with much of the investment shifting toward healthcare and AI as the priority areas in the last two years. At the same time, the central government is exploring methods, including through the establishment of party committees and "special management shares," to exert more influence over large tech companies.

Next, the "Capabilities"section assesses the current state of China's AI capabilities across the four drivers of AI development by constructing an AI Potential Index (AIPI), which approximates countries' overall AI capabilities. For each driver, I find proxy measures that benchmark China's capabilities as a proportion of the global total. Thus, a country's AIPI, scored from 0 to 100, represents its share of the world's total AI capabilities.

- China's AIPI score is 17, which is about half of the U.S.'s AIPI score of 33. China trails the U.S. in every driver except for access to data. One could argue that China's lead in data would outweigh its deficits in other drivers. The AIPI is useful for testing these arguments. I find that the relative importance of the data driver would have to be over four times that of each of the other three drivers for China's AIPI score to equal that of the United States.
- Several caveats are important to note. The index is meant to be a first-cut estimate of the AI landscape, so the specific numbers are not as important as their relative sizes and differences. The methodology will need to be refined as this index is limited by proxy measures for which quantifiable, reliable data was collected for both the U.S. and China.

Finally, I examine the potential implications of China's AI dream for issues of AI safety and ethics, national security, economic development, and social governance. I emphasize that Chinese thinking on these issues is becoming more diversified and substantive. Though it is too early for firm conclusions about the long-term trajectory of China's AI development, it is useful to highlight the key areas of debate in each of these issues:

- One group of Chinese actors is increasingly engaged with issues of AI safety and ethics. A new book authored by Tencent's Research Institute includes a chapter in which the authors discuss the Asilomar AI Principles in detail and call for "strong regulations" and "controlling spells" for AI.[2] A wide range of Chinese AI researchers are also involved with translating the IEEE's Ethically Aligned Design report, as part of the Global Initiative for Ethical Considerations in Artificial Intelligence

2 These terms are from my translations of the book, which are available upon request (Tencent Research Institute et al., 2017).

and Autonomous Systems. However, other Chinese AI leaders dismiss calls for regulation and philosophizing.

- Since military applications of AI could provide a decisive strategic advantage in international security, the degree to which China's approach to military AI represents a revolution in military affairs is an important question to study. The level of civil-military integration will be a critical factor in keeping track of this question.
- Economic benefit is the primary, immediate driving force behind China's development of AI. Per multiple reports, of all economies' worldwide, China's has the most to gain from AI technologies, since AI systems could enable China to improve its productivity levels and meet GDP targets.[3] Initial figures are promising - new Chinese AI companies and investment in the years 2014-2016 surpassed the number of companies and amount of investment in all the years prior[4] - but they should be tempered by the potential for speculative over-investment to cause boom-bust cycles.
- China's adoption of AI technologies could also have implications for its mode of social governance. Per the State Council's AI plan, AI will play an "irreplaceable" role in maintaining social stability, an aim reflected in local-level integrations of AI across a broad range of public services, including judicial services, medical care, and public security.[5] Two key areas to watch are growing concerns about privacy and the willingness of private companies to participate in various social credit systems.

3 PwC, 2017; McKinsey Global Institute, 2017

4 Li, 2017

5 State Council, 2017a; for a full English translation of the "New Generation Artificial Intelligence Development Plan" by a group of experienced Chinese linguists with deep backgrounds on the subject matter, see this document from the New America foundation: https://www.newamerica.org/cybersecurity-initiative/blog/chinas-plan-lead-ai-purpose-prospects-and-problems/.

INTRODUCTION

In his report to the 19th Party Congress in October 2017, Chinese President Xi Jinping reiterated his dream for China to become a "science and technology superpower."[6] Development of AI has become an integral part of China's strategy to realize this goal. One turning point in China's view of AI was the March 2016 victory by Google DeepMind's AlphaGo over Lee Sedol,[7] who is widely considered to be the greatest Go player of the past decade.[8] Two professors who consulted on the State Council's AI plan referred to AlphaGo's mastery of the ancient Chinese strategy game as a "Sputnik moment," prompting immediate reconsideration among government officials of China's AI strategy. [9]

A year later, the State Council issued the "New Generation AI Development Plan" in July 2017, formalizing existing investments in AI and unambiguously signaling China's prioritization of AI development. The plan's specific benchmarks for AI and AI-related industries[10] – including by 2030 a gross output of RMB 1 trillion (U.S. $150.8 billion) for the core AI industry and RMB 10 trillion (1.5 trillion) for related industries – demonstrated China's aspiration to lead the world in the field. While the plan serves as an important milestone in China's AI development, it is still only one piece of China's overall AI strategy. To explain the full picture, this report places the State Council plan and China's broader approach to AI in the context of China's past science and technology plans, as well as the AI strategies of other countries. It then analyzes China's approaches to the growth of different drivers of AI development, and assesses the status and implications of China's growing AI capabilities.

6 Economic Daily [jingji ribao], 2017

7 Borowiec, 2017

8 Deepmind, 2017

9 Mozur, 2017

10 The line between core AI and AI-related industries is fuzzy. In some AI plans, the Chinese government delineates core AI technologies from other related technology types like smart vehicles, smart wearable devices, and smart robots, among others. Under this conceptualization, core AI would include companies innovating in an industry-agnostic part of the AI architecture whereas AI-related industries would include parts of the AI pipeline focused on applications in specific industries. I clarify the term "gross output" in the introduction.

I. CONTEXT

China's AI development plan did not begin with this State Council document in July; rather, the plan both formalizes and definitively signals a focus on AI—one that was already broadly known.[11] For instance, a month before the State Council's report, the government of the Chinese city of Tianjin had announced a USD 5 billion fund to support the AI industry.[12] In this section, the report compares the plan and China's overall AI approach with regard to China's current AI capabilities, as well as the positions of other countries on AI.

A. China's AI expectations vs. current scale of AI industry

The State Council's plan represents the culmination of increased policy support for AI development. The Chinese government has significantly ramped up its AI plans in the past few years (Table 2). AI now appears among a select number of explicit government priorities in key, long-term plans related to science and technology[13], and has backing from substantive funding measures – two key elements not present in past government support for AI.

Released in 2016, the "13th Five-Year Plan for Developing National Strategic and Emerging Industries" (2016-2020) identified AI development as 6th among 69 major tasks for the central government to pursue. The "Internet Plus" initiative, established in 2015, is tightly linked to AI development, as evidenced by the NDRC announcement of an "'Internet Plus' and AI Three-Year Implementation Plan" targeting the creation of an AI market that is hundreds of billions of RMB in size. Moreover, the NDRC, the Ministry of Industry and Information Technology, and the Ministry of Finance jointly released the "Robotics Industry Development Plan (2016-2020)" in April 2016.[14] In 2017, Chinese Premier Li Keqiang incorporated the term "artificial intelligence" into the government's work report[15] for the first time, a development the news department of the State Council covered.[16] Moreover, Chinese President Xi Jinping mentioned AI as a way to increase economic productivity in his opening speech of the 19th Party Congress.[17]

AI-related plans are increasingly tied to substantive funding mechanisms. Notably, in February 2017, the "Artificial Intelligence 2.0" plan received megaproject designation, which comes with substantial funding,

11 Mozur, 2017

12 *Ibid.*

13 In 2016, the Five Year Plan for Developing National Strategic and Emerging Industries (2016-2020) highlighted development of AI as one of 69 major tasks for the central government to pursue; in 2017, "Artificial Intelligence 2.0," a comprehensive effort to boost investment in AI education and development, was adopted as one of 16 Megaprojects in the Five Year Plan for National Science and Technology Innovation.

14 He, 2017

15 The government work report is an annual report on economic growth given by the Chinese premier to the National People's Congress, China's top legislative body. It summarizes the government's efforts last year and outlines crucial tasks for the year ahead. Since the report normally sets the target GDP growth rate for the next year, its content is carefully scrutinized, making the work report an important signalling mechanism.

16 State Council, 2017b

17 Dwnews. 2017

Table 2: Recent AI Plans

Plan	Description	Key Elements	Importance
13th Five Year Plan for Developing National Strategic and Emerging Industries (2016-2020) ["十三五" 国家战略性新兴产业发展规划]	A State Council policy document which specifies implementation measures for the 13th Five-Year Plan, focused on strategic industries	Highlighted development of AI as 6th among 69 major tasks[a] for the central government to pursue; Identified five agencies responsible for developing central government policies in AI in the next five years	Links AI to the current Five Year Plan through this guiding plan
"Internet Plus" and AI Three-Year Implementation Plan (2016-2018) ["互联网+" 人工智能三年行动实施方案]	Jointly issued by the National Development and Reform Commission (NDRC)[b], the MoST, MIIT, and the Cyberspace Administration of China	Established a goal to grow the scale of the AI industry's market size to the "hundreds of billions" (RMB)	Connects AI development to highly touted "Internet Plus" policy which aims to catapult China to becoming a digital powerhouse
Robotics Industry Development Plan (2016-2020) [机器人产业发展计划]	Plan to develop robotics industry released by the NDRC, the MIIT, and the Ministry of Finance (MOF)	Set specific targets for advancing the robotics industry; the second of two development plans containing a focus on AI released by central agencies with a policy planning mandate	Sets goal of manufacturing 100,000 industrial robots annually by 2020, making China the world's leading robot-maker
"Artificial Intelligence 2.0" [人工智能2.0]	Proposal by Chinese Academy of Engineering added to a list of 15 "Sci-Tech Innovation 2030 – Megaprojects"[c]	Megaprojects were proposed and finalized in 2016 with the release of the "13th Five-Year Plan for National Science and Technology Innovation" but AI was added in Feb. 2017	Demonstrates how AI was elevated to the level of a megaproject only recently
Three-Year Action Plan for Promoting Development of a New Generation Artificial Intelligence Industry (2018-2020)	MIIT action plan for implementing tasks related to State Council's AI Plan and "Made in China 2025"	Sets out specific benchmarks for 2020 in a range of AI products and services, including smart, inter-connected cars, and intelligent service robots	Shows government's strong guiding role in developing the AI industry (convened top 30 companies to develop indicators)

[a] Priorities listed above AI development, ordered from first to fifth: constructing internet network infrastructure, including rural broadband projects; improving radio and television networks; promoting "Internet Plus"; implementing big data development projects; and strengthening information and communications technology industries (State Council, 2016).

[b] The NDRC is the Chinese government's central economic planning ministry. It has significant powers in allocating investment funds and approving major projects and has been dubbed China's "mini State Council" and "number one ministry." In recent years as President Xi's administration has stressed a "decisive role for market forces, the NDRC has tried to reposition itself as a macroeconomic coordinator that is more relevant to a market-driven Chinese economy (Martin, 2014).

[c] For context, the original 15 S&T Innovation Megaprojects (2030) were announced in July of 2016, so AI was added on 7 months later to make 16 total projects. Focus areas for the other 15 include quantum communication, national cyberspace security, and neuroscience. These megaprojects are not new policy innovations. The "National Medium- and Long-Term Plan for the Development of Science and Technology (2006-2020)" also established 16 S&T Innovation Megaprojects to end in 2020. If past megaprojects are any precedent, the AI megaproject will likely involve a combination of significant grant money and various other policy levers (R&D tax credits, investment in talent pipeline, promotion of technical standards). The "mega-project" approach has been criticized by US-based scientists who are involved with the Chinese Academy Science for diverting resources from supporting investigator-driven projects. Another cynical take on megaprojects is that they are merely a repackaging of existing MOST programs and national programs administered by other agencies (Cao, Suttmeier, and Simon, 2006; Springut, Schlaikjer, and Chen, 2011).

alongside fifteen other technologies deemed crucial to China's science and technology innovation.[18] Additionally, the Fund for Industrial Restructuring and Upgrading allocated RMB 2.78 billion (USD 404.3 million) to projects in smart manufacturing in 2016 alone, and the 2017 Central Basic Infrastructure Budget allocated a combined RMB 5.28 billion (USD 614 million) to infrastructure for "Internet Plus" and "key projects in emerging industries" in 2017.[19] Two other trends are notable. First, the history of China's government support for AI-related development demonstrates a consistent emphasis on robotics and indigenous innovation, an indication that smart manufacturing will continue to be a priority. Second, bureaucratic agencies have begun to compete for authority over AI policy, a trend highlighted by the fact that the State Council has tasked 15 offices with implementing their AI plan.[20]

Analyzing the State Council plan's targets for the growth of China's AI industry in context of the current scale of its AI industry confirms China's high expectations for AI development. The plan outlines an ambitious three-stage process toward achieving China's dream of leading the world in AI:[21]

> 1) By 2020, China's AI industry will be "in line" with the most advanced countries, with a core AI industry gross output exceeding RMB 150 billion (USD 22.5 billion) and AI-related industry gross output exceeding RMB 1 trillion (USD 150.8 billion).[22]
>
> 2) By 2025, China aims to reach a "world-leading" level in some AI fields, with a core AI industry gross output exceeding RMB 400 billion (USD 60.3 billion) and AI-related industry gross output exceeding RMB 5 trillion (USD 754.0 billion).
>
> 3) By 2030, China seeks to become the world's "primary" AI innovation center, with a core AI industry gross output exceeding RMB 1 trillion (USD 150.8 billion) and AI-related gross output exceeding RMB 10 trillion (USD 1.5 trillion).

Conceptually, these benchmarks map neatly onto three strategic phases of AI development: (1) catching up to the most advanced AI powers, (2) becoming one of the world leaders in AI, and (3) achieving primacy in AI innovation.

Unpacking the context behind the target numbers helps illustrate the degree of aspiration behind China's AI push. According to iiMedia Research Group's "2017 Special Report on China's Artificial Intelligence Industry,"[23]

18 New Intellectual Report [xinzhiyuan baodao], 2017

19 He, 2017

20 China Economic Net [zhongguo jingjiwang], 2017

21 These are my translations of the report. Emphasis mine.

22 Some English-language reports on these benchmarks have translated them as "industry scale" or "market size" indicators, but the more precise translation is "gross output," a measure of the production side of specific industries. An industry's gross output is the sum of sales to final users in the economy (GDP) and sales to other industries (intermediate inputs). For a frame of reference, the estimated gross output of China's robotics industry in 2017 was U.S.$6.8 billion. I cover the distinction between core AI and AI-related in the next two paragraphs.

23 iiMedia, 2017

China's AI industry had a gross output of RMB 10 billion in 2016, and is expected to grow to around RMB 15 billion in 2017. Thus, the 2020 benchmark for the core AI industry's gross output (RMB 150 billion) would represent a tenfold increase of the AI industry in the next three years.[24] China's ambitions in AI can also be understood in the context of the global AI industry. Per a report by McKinsey Global Institute, forecasts of the global market size for AI in 2025 range from USD 644 million to USD 126 billion.[25] If these projections refer to core AI industries, China's 2025 benchmark for a USD 60.3 billion, world-leading core AI industry corresponds with the high end of market forecasts for AI.

To be clear, the line between core AI and AI-related industries is fuzzy, so how China's State Council interprets the difference between the two is important to analyze. The slipperiness of what exactly constitutes AI is a problem that plagues analysis of AI strategy. The flip side of this slipperiness is AI's "omni-use" potential (i.e. its similarity to electricity), which I investigate later by comparing it to other technologies. Perhaps the most credible distinction in the Chinese context can be found in the "Internet Plus" and AI Three-Year Implementation Plan issued by the NDRC. This plan outlines nine major technology areas, listing "core AI technologies" along with eight other technology types. These "core AI technologies" include basic research in fields such as deep learning, the development of basic software and hardware such as chips and sensors, and applied research in areas like computer vision and cybersecurity.[26]

Notably, these core AI technologies are differentiated from the other eight technology types, which include smart vehicles, smart wearable devices, and smart robots, among others. The implementation plan's definition of "core AI" fits with that of CB Insights, a leading market research firm, which defines "core AI companies" as those focused on general-purpose AI applicable across a variety of industries.[27] Under this conceptualization, core AI would include companies innovating in a specific, industry-agnostic part of the AI architecture, whereas AI-related companies would include parts of the AI pipeline focused on applications in specific industries.

B. China's AI ambitions vs. other countries' AI strategies

Some Chinese AI experts and decision-makers are keenly aware of the AI strategies and capabilities of other countries, in particular the United States, the EU, Japan, and the United Kingdom. In a chapter titled "Top-level Plans," scholars from Tencent's Research Institute and the China Academy of Information and Communications Technology, a research institute under the Ministry of Industry and Information Technology (MIIT), laid out their view of the current international strategic landscape for AI development as follows:[28]

- **'Defend the lead' America — a comprehensive, strategic layout:** "In sum, the United States is,

24 The State Council may be working off of a different estimate for the current gross output of the core AI industry. This calculation assumes that the iiMedia Research Group's estimate is close to what the State Council views as ground truth.

25 McKinsey Global Institute, 2017b

26 He, 2017

27 CB Insights Research, 2017

28 This arrangement is from my translations of a book published by Tencent on AI strategy (Tencent Research Institute et al., 2017).

at this point, the country that has introduced the most strategies and policy reports on artificial intelligence strategies. The United States is undoubtedly the forerunner in the field of artificial intelligence research and its every move necessarily affects the fate of all of humanity."

- **Ambitious EU — 'Human Brain' and 'SPARC' Projects:** "In 2013, the European Union proposed a 10-year Human Brain Project, currently the most important human brain research project in the world."
- **Robot superpower Japan — 'New Industrial Revolution':** "For the past 30 years, Japan has been called the "robot superpower" and has the world's largest number of robot users, robotics equipment, and service manufacturers."
- **Unwilling to fall behind Britain — facing the fourth industrial revolution challenge:** "The UK considers itself to be a global leader in ethical standards for robotics and AI systems. At the same time, this leadership in this area could extend to the field of artificial intelligence regulation."

As for the authors' assessment of China's own position within this landscape, they titled China's section as "China, from 'running after' to 'setting the pace'," and wrote the following, "In terms of AI, China followed the United States and Canada in releasing a national AI strategy. In the wave of AI industry, our country should go from system follower and move towards being a leader, actively seizing the strategic high ground." [29] This concept of "setting the pace" is essential to understanding China's high ambitions for its AI development.

Second, there is evidence that China is particularly attuned to U.S. AI strategy, and sees it as a reference point for its own approach. Many key junctures in China's AI development are related to significant AI-related pronouncements that are linked to the United States. For instance, after the Department of Defense's announcement of the "Third Offset" strategy in 2014 – which Chinese defense analysts and policymakers followed closely – the Chinese military establishment responded by revising its modernization approach to increase investments into AI technologies.[30] China also reacted to other significant developments in U.S. AI policy. In October 2016, the Obama administration released the first of three reports on AI, which also corresponded with a large spike in Baidu searches for AI. Some analysts have noted similarities between the State Council's AI plan and these three reports, suggesting that the drafters of China's AI plan were closely familiar with the previous U.S. administration's policy statements.[31] In 2016, the biggest spike in Baidu searches (the Chinese equivalent of Google searches) for "artificial intelligence" [人工智能] occurred right after AlphaGo's victory, per a report by the Wuzhen Institute.[32] Chinese leaders and scholars also paid significant attention to AlphaGo's victory. After AlphaGo's win in February 2016, high-level seminars and symposiums were conducted on the implications. One such event was "A Summary of the Workshop on the Game between AlphaGo and Lee Sedol and the Intelligentization of Military Command and Decision-Making" (围棋人机大战与军事指挥决策智能化研讨会观点综述), which took place in April 2016 and included PLA thinkers from the Academy of

29 *Ibid.*

30 Wood, 2017

31 Allen and Kania, 2017

32 Wuzhen Institute, 2017

Military Science and the Central Military Commission.[33]

There are multiple ways to interpret what lessons Chinese decision-makers took away from these critical junctures. While AlphaGo shocked the entire world, its victory over Lee Sedol appeared to have particularly affected China, where the game was invented.[34] Perhaps concerned that AlphaGo's mastery of Go would sting the country's national pride, the Chinese government banned outlets from covering its May 2016 match with the Chinese player Ke Jie, the world's number one player at the time.[35] For China, AlphaGo may have demonstrated that advances in AI are linked to national prestige and the perceived status of great powers. Additionally, the types of high-level seminars conducted after AlphaGo indicate that some Chinese policymakers interpreted AlphaGo's victory as having significant implications for military affairs. Per testimony before the U.S.-China Economic and Security Review Commission by Elsa Kania, the PLA "anticipates the advent of artificial intelligence will fundamentally alter the character of warfare, ultimate resulting in a transformation from today's 'informatized' ways of warfare to future 'intelligentized' warfare."[36] Another reasonable hypothesis is that China's reaction to major American AI-related developments, including the way in which the State Council's plan was drafted, is partly inspired by U.S. strategy.[37] Under this interpretation, the U.S. government may have some degree of influence in shaping a potential template for China's AI planning.

33 China Military Science Editorial Department [zhongguo junshi kexue bianjibu], 2016 cited in Kania, 2017

34 Hern, 2017

35 *Ibid.*

36 Kania, 2017

37 This may fall prey to a "mirror-imaging" bias, the assumption that another actor will react to and interpret events in the same way as one-self (Inkster, 2016).

II. COMPONENTS

A. Key consistencies and differences with other science and technology plans

Much of China's approach to AI is old in the sense that it is consistent with past science and technology plans. While there are also some critical new factors, the features that stay consistent are important to highlight because they can be mined for empirical examples. Chinese government support for AI development, emphasis on indigenous innovation, and prioritization of frontier technologies traces back to February 2006, when the State Council issued their "National Medium- and Long-Term Plan (MLP) for the Development of Science and Technology (2006-2020)." At the time, the MLP was Beijing's most ambitious science and technology plan to date. It allocated long-term funding for science research, estimated at RMB 500 billion (USD 75 billion), and launched sixteen national megaprojects for developing vanguard science and technology, including programs for integrated circuit manufacturing and large advanced nuclear reactors.[38] Indeed, the designation of "Artificial Intelligence 2.0" as a megaproject follows the framework set by the MLP. The plan also contained an explicit target to strengthen indigenous innovation. China's "Made in China 2025" initiative, released in May 2015, further emphasized the need for indigenous innovation to reduce the country's dependence on other countries for high-end manufacturing.

In the drafting of the MLP, infighting among Chinese scientists and bureaucrats became so serious that it leaked out into the public sphere, an underappreciated aspect of Chinese science and technology policy that also applies in the AI context. In the early 2000s, Premier Wen Jiabao brought together the Chinese Academy of Sciences (CAS) and the Ministry of Science and Technology (MoST) to draft this MLP: in total, 2000 bureaucrats, researchers, and business managers were involved in the drafting process.[39] As the bureaucrats at MoST and MIIT gradually shifted the direction of the MLP toward megaprojects, Chinese scientists bristled at the degree of control given to bureaucrats over scientific inquiry. In fall of 2004, a group of prominent Chinese scientists, from both inside and outside of China, published a collection of essays in a special issue of Nature that criticized the draft MLP plan.

There is some evidence that similar infighting has already begun over AI policy. The "'Internet Plus' and AI Three-Year Implementation Plan" gives four agencies – the NDRC, the MoST, the MIIT, and the Cyberspace Administration of China – the mandate to advance the AI industry. In contrast, the State Council's "New Generation AI Development Plan" called for the establishment of an AI Plan Implementation Office under the authority of MoST. None of the other bureaucratic entities involved with the "'Internet Plus' and AI Three-Year Implementation Plan" received mention in the State Council's new plan, a notable exclusion given how comprehensive the document is in other respects. One researcher at the Council on Foreign Relations posited that this was an instance of bureaucrats at MoST asserting their claim on high-tech developments, undercutting

38 Bitzinger and Raska, 2015

39 McGregor, 2010

the authority of other ministries or academic efforts.[40] In December 2017, MIIT issued its own three-year action plan to implement tasks related to the State Council's plan and "Made in China 2025." When the AI Implementation Office was officially created four months later, the official number of agencies involved had risen to 15 offices. Two offices, MoST and NDRC, were named in the announcement, ensuring that bureaucratic infighting over China's AI path will not cease anytime soon.[41] Although the central government plays an important guiding role, bureaucratic agencies, private companies, academic labs, and subnational governments are all pursuing their own interests to stake out their claims to China's AI dream.

Lastly, there are important similarities and differences between China's approach to AI development and its past efforts to spur innovation in strategic, emerging technologies. Take the example of biotechnology. The model of ramping up state support and intervention is similar to AI. First, there was a modest "climbing program," which was initiated in the 1980s and lasted about eight years before the government made biotech more of a priority.[42] Second, the Chinese government set up an independent entity, China National Center for Biotechnology Development, to coordinate the development of biotech, and important central planning documents begin to focus on the technology, in particular the State Council's National Biotechnology Development Policy Outline in 1988, which established thirty national key laboratories.[43] Third, the government signaled that biotech was a national-level priority and committed substantial funding toward its development. For example, the 863 program, China's main vehicle for science and technology funding at the time, designated biotech as one of seven critical areas, and allocated around 1.5 billion RMB toward its development over the years 1986 to 2000.[44]

Other consistencies between China's biotech strategy and AI approach include: international transfer of both technology and talent, as well as investment in whole-of-society and long-term measures. In the domain of tech transfer, Chinese firms in the pharmaceutical, biotech, and healthcare industries reached a record amount of $3.9 billion in overseas acquisitions in 2016.[45] Talent programs have also attracted overseas Chinese working at the cutting edge of bioscience. "Deng Xiaoping sent many Chinese students and scholars out of China to developed countries 30 to 40 years ago, and now it is time for them to come back," stated George Fu Gao, who received his doctorate at Oxford, of the Chinese Academy of Science's Institute of Microbiology.[46] There are also signs that China's long-term investments in biotechnology are bearing fruit over thirty years later, as evidenced by recent advancements on cloning techniques and research on viral epidemics.[47] However, China contributes relatively little to fundamental research: only 2.5 percent of the new molecules discovered from 2007 to 2015 came from China, compared to 56.3 percent from America.[48]

40 Council on Foreign Relations, 2017
41 China Economic Net [zhongguo jingjiwang], 2017
42 Huang and Wang, 2003
43 *Ibid.*
44 *Ibid.*
45 Bloomberg, 2016
46 Ball, 2018
47 *Ibid.*
48 Bloomberg, 2017

Significant differences between China's AI policy and biotech policy are rooted in two factors: AI's "omni-use" potential means the breadth of actors involved is much wider than for other technologies; internationally-facing, private tech giants and vigorous startups are leading players in driving innovation in AI. Even the influence of the largest biotech companies pales in comparison to the power and sheer size of China's tech giants. Consider the case of China's genomic giant BGI, which has produced a number of major breakthroughs in genome sequencing. Its initial public offering raised $81 million, which is around 1/300 the size of Alibaba's IPO.[49] One could argue that it is unfair to take Alibaba's IPO as the proxy for its influence in shaping AI development, because the IPO encompasses all of Alibaba's business portfolio. That Alibaba announced in October 2017 an investment of $15 billion in AI-related R&D, with foci on quantum computing and human-machine interaction, serves as an effective rebuttal to that argument.[50] Finally, core AI technologies are more fundamental than biotechnologies. That is, innovations in AI algorithms can revolutionize BGI's genome sequencing, whereas the relationship does not operate in reverse. So while there are many similarities among China's AI strategy and its aims for other strategic, emerging technologies, the immense power of tech companies and AI technology itself mark out key differences.

B. Channels from these key features to drivers of AI development

A comprehensive assessment of the components of China's AI strategy requires an understanding of the broad range of drivers related to the AI development, including: (1) hardware in the form of chips and supercomputing facilities, (2) data as an input for AI algorithms, (3) research and algorithm development, and (4) the commercial AI ecosystem. Analyzing China's current landscape for each of these drivers clarifies crucial features of its strategy to become a world leader in AI (Table 3).

With respect to hardware for AI algorithms, China's promotion of national champions, encouragement of

Table 3: Key features of China's AI Strategy

Main driver	Old features	New features
Hardware	Promote national champions, encourage overseas deals, build supercomputers	Tech giants and unicorn startups invest in AI chips
Data	Share data between gov. and companies, protectionist toward cross-border flows	Increasing privacy concerns toward AI applications
Research and Algorithms	Support for basic research, gathering and training talent	Tech giants establish overseas institutes to recruit AI talent
Commercial AI Sector	Set up government guidance funds, picking winners	More actors involved (startups, local governments, agencies, etc.) due to omni-use capabilities

49 Philippidis, 2017

50 Lucas,2017

overseas acquisitions to facilitate technology transfer, and investment in supercomputers[51] are all consistent with past approaches to spurring innovation in strategic technologies. First, it promulgated a national semiconductor policy in June 2014 that prioritized support for "national champions," such as Tsinghua Unigroup.[52] The policy launched a national Integrated Circuit Fund, which has raised more than $20 billion so far,[53] with a goal to raise USD 138 billion total in funds to seed semiconductor investors throughout the country.[54] In October 2017, China's MoST announced a project to invest in chips that run artificial neural networks; as one of 13 "transformative" technology projects with a delivery date of 2021, the AI chip project specifically references Nvidia's M40 chip as a benchmark, aiming to beat the M40's performance and energy efficiency by 20 times.[55]

Second, the Chinese government has encouraged domestic companies that enjoy political support to sign deals with international firms to facilitate access to high-quality chip technology.[56] A January 2017 report by the U.S. President's Council of Advisors on Science and Technology on the semiconductor industry noted that Chinese firms have been increasingly active in the acquisition space and that China places conditions on access to its market in order to incentivize technology transfer.[57] Recently, China's two-pronged strategy has faced increased international scrutiny. After the U.S. government banned Intel and other chip-makers from selling China high-powered Xeon chips,[58] the Committee on Foreign Investment in the United States (CFIUS) has subjected China's investments in U.S. chip-makers to harsher scrutiny. In September 2017, the White House blocked a state-backed Chinese investment fund from acquiring a US semiconductor company, marking only the fourth time in history that an American president had blocked a corporate acquisition on national security grounds.[59]

A similar story has played out in Europe. In his 2017 State of the European Union Speech, Jean-Claude Juncker, president of the EU Commission, rolled out a new framework for screening foreign direct investments into the European Union. The framework identified critical technologies including, "artificial intelligence, robotics, semiconductors, technologies with potential dual-use applications, cybersecurity, space or nuclear technology."[60] While Juncker's speech did not explicitly call out Chinese investments, analysts interpreted his warnings about investments from "state-owned companies" as an implicit reference to China's economic activities.[61]

Third, China has made long-term bets on building supercomputing facilities. A few top-line figures indicate that China has made significant advances in the hardware necessary to power these potential breakthroughs. For

51 To date, it is uncertain whether supercomputers can spur AI-related progress. Chinese supercomputers, based on their own chips, have only been used for scientific projects and the chips have not been sold on the commercial market. I thank Jimmy Goodrich for this point.

52 Orr and Thomas, 2014

53 McKinsey Global Institute, 2017a

54 Weinland, 2017

55 Simonite, 2017

56 Ray et al. 2016

57 President's Council of Advisors on Science and Technology, 2017

58 Tomson, 2015

59 Donnan, 2017

60 Fischer, 2017

61 John, 2017

instance, China surpassed the U.S. to have the most supercomputing facilities in the world at 167, compared to 164 in the U.S.,[62] and China's Sunway TaihuLight, which uses Chinese-designed processors, became the world's fastest system in June 2016.[63] Since much of the link to AI is speculative, I do not include these metrics in my index of AI capabilities, but some have argued that China's long-term commitments to supercomputing facilities, along with its funding for quantum computing, may have real applications for AI.[64]

What is new in the hardware driver is that Chinese tech giants and unicorn startups are competitive with some of the world's leading companies in designing AI chips. For instance, Chinese company Cambricon, a state-backed startup valued at $1 billion, has developed chips that are six times faster than the standard GPUs for deep learning applications and use a fraction of the power consumption.[65] Moreover, equipped with a new "neural processing unit," Huawei has arguably overtaken Apple in mobile AI chips.[66]

The Chinese government's policies on the second driver, access to data, reveal two other critical aspects of its broader AI strategy: its leverage over big tech companies and its tendency toward protectionism. In October of 2016, some of China's largest tech companies agreed to share data with government authorities to improve consumer trust online.[67] The NDRC stated that the agreement was part of a broader project to create a national "social credit system," which some privacy advocates have argued is designed for mass surveillance.[68] As AI-fueled tech companies like the BAT companies become more and more powerful, the Chinese government has pushed for more influence over these big tech giants, even discussing the possibility of internet regulators taking 1% stakes in the companies.[69] Dubbed "special management shares," these small stakes would give Chinese government officials positions on company boards and the right to monitor content on the company's online platforms.[70]

China's sharing of data stops at the water's edge. This fits with a larger trend of what some deem China's techno-nationalism, an approach that aggressively protects domestic companies from foreign competitors.[71] Even if the Chinese companies that rise from this approach do not compete internationally - though many have successfully expanded to Asian and African countries - they still thrive by serving China's huge market. Data security concerns have motivated China's efforts to ensure valuable data stays under the control of Chinese tech companies. In this vein, China has pushed for national standards in AI-related industries, such as cloud computing, industrial software, and big data, that differ from international standards, a move that may favor Chinese companies over foreign companies in the domestic market. According to a Mercator Institute report,

62 McKinsey Global Institute, 2017a

63 Vincent, 2016

64 Costello, 2017

65 Giles, 2017

66 Vincent, 2017

67 Clover and Ju, 2016

68 *Ibid.*

69 Yuan, 2017

70 Zhong and Wee, 2017

71 For a history of this term, See: Feigenbaum, 2017

Chinese standards for smart manufacturing, cloud computing, industrial software, and big data differ significantly from the international standards in those domains.[72] Data protectionism, such as the 2017 cybersecurity law that prevents foreign firms from storing data collected on Chinese customers outside of China, could disincentivize cross-border data pooling and the development of common standards for data sharing.[73]

One unique aspect of China's AI development in the data driver is the emergence of a major debate over data privacy protections.[74] Companies, different levels of government, and even the general public have been active participants in this debate, which pits those advocating for greater data privacy protections against those pushing for data liberalization to benefit AI technologies.[75] In a chapter titled "Top-level Plans," Tencent and CAICT researchers attribute the success of Silicon Valley to the existence of strong institutions such as copyright and tort law, and they argue that data liberalization is a form of institution building that could spur further innovation. They write, "If there is no government data liberalization policy, many AI applications will become 'water without a source, a tree without roots.' It can be said that the issue of data liberalization is a pain point in the development of AI in China and needs to be elaborated upon in a more comprehensive and in-depth manner in the strategy." Recently, in January 2018, advocates for data privacy celebrated when the Chinese government released a new national standard on the protection of personal information, which contains more comprehensive and onerous requirements than even the European Union's General Data Protection Regulation, per analysis by CSIS senior fellow Samm Sacks.[76] This vigorous and unresolved debate over data privacy combats common misperceptions of China's relatively lax privacy protections and is an important one to follow as China advances in AI.

In order to incentivize top quality-AI research and development, the State Council's AI plan dedicates a section to accelerating the training and gathering of high-end AI talent.[77] In the "gathering" section, the report calls for recruiting top international scientists through a variety of "Thousand Talents" plans. China's Ten Thousand Talents program, launched in 2007 with substantial financial backing,[78] has enticed talented scholars in AI-related fields to work in China. Andrew Chi-Chih Yao, a Turing Award[79] winner who renounced US citizenship, is now researching "AI theory development." Additionally, Tim Byrnes, an Australian physicist is aiming to develop a quantum computer at NYU Shanghai, and Zhang Liang-jie, a former research staff member at IBM Watson, will investigate AI and virtual reality as chief scientist at enterprise software group Kingdee in Shenzhen.[80] Lastly, Zenglin Xu, a former research associate at Purdue University, who now leads the statistical

72 Wübbeke et al, 2016

73 The Economist, 2017

74 I thank Danit Gal for pointing me toward this discussion.

75 Sacks, 2018

76 *Ibid.*

77 State Council, 2017a

78 There are three main "Thousand Talents" Programs: 1. The "Long-Term Thousand Talents Program" awards grants of RMB 3 million (USD 452,000) to work full-time in China, as well as a one million RMB (USD 151,000) allowance; 2. The "Short-Term Thousand Talents Program requires hired employees to work in China for at least two months per academic year - talents will receive a RMB 500,000 (USD 75,000) allowance; 3. The Thousand Talents Program for Distinguished Young Scholars provides RMB 1-3 million (USD 151,000-USD 452,000) in research funding from the central government, an additional RMB 700,000 (USD 105,000) in research funding from the Chinese Academy of Sciences, as well as a RMB 600,000 (USD 90,376) allowance. Per the Chinese Academy of Sciences: http://english.ucas.ac.cn/index.php/join/job-vacancy/2040-the-long-term-thousand-talents-program

79 The Turing Award is often referred to as "the Nobel Prize of Computing."

80 Lucas, and Feng, 2017

machine intelligence and learning lab at the University of Electronic Science and Technology of China, moved back to China through a portion of the Ten Thousand Talents program dedicated to attracting young academics.[81]

China's talent programs have a mixed track record. From 2009 to 2011, the Thousand Talents program may have attracted the largest influx of high quality talent within a limited timeframe in all of China's history, per data released by the Chinese Academy of Personnel Science.[82] In those three years, 1510 scientists were selected as talent program awardees at the national level, out of an application pool of 6200.[83] However, multiple empirical studies and interviews with recruiters for the talent programs reveal that these programs have not managed to attract the "best and brightest" Chinese scientists to return.[84] A multitude of factors play a role, including: a research culture focused on instant results, lack of connection with domestic Chinese networks to advance, and problems with educational opportunities for their children. Nonetheless, as China works to reform its research culture and ramps up its efforts to encourage researchers to work in China, particularly those of Chinese descent, it could expand China's pool of AI experts, as China's scientific diaspora numbers over 400,000 scientists and other scholars.[85]

Talent transfer also occurs through commercial avenues: an investor who specializes in AI identified the strategy of hiring talented AI scientists to work in China - where salaries are now comparable to those in America, ranging from 70-150% of average pay for U.S. AI scientists - as a "shortcut" to accelerate AI development.[86] In order to recruit foreign talent, the BAT companies have established their own overseas AI institutes.[87] World-leading AI talents have returned to China for work: Andrew Ng, former head of Google Brain, worked at Baidu for three years, and Qi Lu, former executive vice president of Microsoft, now serves as Baidu's Chief Operating Officer. Headhunters working for China's city governments and technology companies regularly visit international scholars and engineers in universities, companies, and startups and attempt to convince them to work in China.[88] These different channels for talent transfer reveal an important point about China's AI strategy - it is not a monolithic, completely top-down approach; many actors are maximizing their own interests and responding to broad signals from the central government.

Finally, China is taking the long-view to growing AI talent. The State Council's plan also calls for constructing an AI academic discipline, involving a comprehensive effort to establish AI majors, create AI institutes in pilot

---

81 Zenglin Xu's curriculum vitae is available at: http://www.bigdata-research.org/people/faculty/5.html. Note that Xu has won travel grants for NIPS and ICJAI.

82 Zweig and Wang, 2013

83 *Ibid.*

84 Cao, 2008

85 Schiermeier, 2014

86 Harbringer, 2017

87 Alibaba recently invested USD 15 billion into global R&D, including 7 overseas labs, with a priority on AI; Baidu now has two research labs in Silicon Valley; and Tencent has established a lab in Seattle.

88 South China Morning Post, 2017

institutions, and include "AI + X" hybrid professional training.[89] This whole-of-society push is a trademark of China's central-guided development, and it demonstrates that China is placing a long-term bet on AI.[90] While the government encourages the flow of talent and technology into Chinese AI sector, it prevents foreign companies from establishing a foothold in critical, AI-related sectors and restricts the flow of data out of China. The door is half open: China seeks to benefit from the open flow of talent and technology, while preventing international companies from gaining a foothold in its AI industry.

In the last driver regarding the commercial AI ecosystem, the Chinese government actively picks winners in the AI space. For example, in November 2017, MoST designated four companies — Baidu, Alibaba, Tencent, and iFlyTek — to lead the development of national AI innovation platforms in self-driving cars, smart cities, computer vision for medical diagnosis, and voice intelligence, respectively.[91] These national endorsements could give Baidu an advantage in working with car manufacturers and Tencent wider access to hospital data, but they may also dampen competition in these specific markets.

The Chinese government is beginning to play a larger role in funding AI ventures. Disbursing funds through "government guidance funds" (GGF) set up by local governments and state-owned companies, the government has invested more than USD 1 billion on domestic startups.[92] Per statistics from Sun Hung Kai Financial, these GGFs are projected to eclipse China's private VC funds in size: for the year 2016, GGFs set a total fundraising target of RMB 3.3 trillion (USD 500 billion) vs. a RMB 2.2 trillion (USD 330 billion) total raised by private funds.[93] One report on GGFs noted that from 2015 to 2016, the direction of GGF investment shifted toward healthcare and AI as the main priority areas.[94] There is some initial evidence that increased GGF attention to AI has met some initial success. Per a 2017 report, China has a higher percentage of AI companies that have received investments (69%) than the U.S. (51%).[95] Additionally, the velocity of AI investment is relatively fast: from incorporation to receiving angel investment, the average time for Chinese companies is 9.73 months while it is 14.82 months for US companies.[96] These funds may help the central government achieve two goals at once, helping speed up AI development while also incorporating tech companies within the party apparatus. In the past few years, more than 35 tech companies, including Baidu and Sina, have created company party committees, which evaluate the company's operations to ensure the party's objectives are being followed.[97]

In some respects, the success or failure of China's AI commercial sector will be a test of China's unique mode of public-private partnerships. For reference, funding schemes similar to China's GGFs were instrumental in transforming Israel into a leading technological powerhouse. Advantages for these types of government vehicles

89 State Council, 2017a
90 Council on Foreign Relations, 2017
91 Jing and Dai, 2017
92 Yang, 2017
93 *Ibid.*
94 GYZ Holdings, 2017
95 Li, 2017
96 *Ibid.*
97 Feng, 2017

include policy support, ample resources, and in some cases, a guaranteed minimum return for investors.[98] But the fact that there has not been a single successful exit for any of the 911 GGFs to date reflects the scheme's myriad issues, such as geographical and industry sector restrictions on investment and complicated exit procedures.[99]

Lastly, in all the drivers of AI, China is investing in long-term, whole-of-society approaches to advancing AI technologies. Indeed, the directives laid out in the State Council's AI plan not only apply across government departments but they also strongly guide the actions of universities, research institutes, and the private sector. In contrast, other governments— limited in its power over society and subject to sudden policy shifts depending on which political party is in power — tend to implement short-term, whole-of-government solutions. What follows is an evaluation of how these components of China's AI development have influenced its actual capabilities along the range of four drivers , captured by a series of comparative, quantitative metrics.

98 Xiang, 2017

99 *Ibid.*

III. CAPABILITIES

In the four following sections, this report explains the importance of each driver in detail, so it will draw out some broader points about the relationship among drivers here. First, though this report analyzes each of the drivers separately, connections between drivers cannot be ignored. For instance, hardware improvements (e.g. the development of GPUs) have enhanced the performance for AI algorithms, and innovation algorithms have, in turn, enabled more efficient use of larger amounts of hardware through parallelization (running a program on multiple processors).[100] Second, the importance of each driver relative to the others is the subject of much debate. When AI experts were surveyed on the sensitivity of AI progress to various drivers, opinions varied widely and no consensus was reached on the relative importance of each input.[101] Other analysts have pointed out that the relative weighting of each driver has and will change over time, subject to significant trends like open access to advanced algorithms or large datasets.[102] In the last part of the "Capabilities" section, this report assesses how adjusting the relative weight of each driver could change assessments of China's AI capabilities.

A. Evaluation of China's current AI capacities by driver

i. Catch-up approach in hardware

Due to their high initial costs and long creation cycle, processor and chip development may be the most difficult component of China's AI plan. Currently, AI hardware falls into two categories: (1) chips originally designed for other computing processes but used to train AI algorithms (e.g. CPUs and GPUs) and (2) chips designed specifically to execute machine learning and deep learning algorithms (e.g. Google's TPUs and Microsoft's FPGAs).[103] While the manufacturing of chips these two categories are more immediately relevant for running AI algorithms, supercomputing facilities may become relevant for future AI development if researchers are better able to leverage the benefits of co-located, interconnected compute.[104]

In the first category of hardware, measures of the strength of China's semiconductor industry reveal a potential bottleneck for AI development. General metrics for traditional semiconductor firms are important to consider since these firms are scaling up their own processors to handle AI software, as well as acquiring startups that are building AI chips. In the year 2015, China only had 4% of the global market share of semiconductor production, while the U.S. accounted for 50% of the global market share.[105] This correlates well with total financing figures which show that total financing for China's semiconductor industry was only 4.3% of the amount for its

100 Brundage, 2016

101 AI Impact,s 2016

102 Cronin, 2016

103 CPU stands for central processing unit and is used for general purposes processing; GPU is a graphics processing unit, which was originally designed to process images but happen to be very efficient at training machine learning algorithms. A tensor processing unit (TPU) is a type of application-specific integrated circuit (ASIC), specialized for AI applications. Field-programmable gate arrays (FPGA) chips are reconfigurable, programmable hardware that are relatively efficient for AI applications.

104 I thank Miles Brundage and Allan Dafoe for this point.

105 International Trade Administration, 2016

U.S. counterpart, per a IT Juzi and Tencent Research Institute report.[106] China is particularly dependent on international companies for GPUs, which are the best option for training AI algorithms. Microsoft AI researcher, XD Huang labels GPUs "the real weapon," saying that without GPUs, a Microsoft project that recognizes certain conversational speech as well as humans would have taken 4 years longer to complete.[107] Out of the top 10 American chip-makers, 4 specialize in making GPUs; whereas from the top 10 Chinese chip-making companies, none specialize in GPUs.[108]

In the second category of hardware, chips like TPUs and some ASICs are designed specifically to rapidly execute neural networks.[109] Of the top 10 Chinese chip-makers, 6 specialize in ASIC chips, which are not as flexible as other chips in this category, such as FPGAs which provide high, efficient performance as well as flexibility to change the underlying hardware to adjust to rapidly changing software.[110] Both the U.S. and China have two chip-making companies which specialize in FPGA chips out of their top 10 chip-making companies; the two U.S companies received a total of 192.5 million in total financing, while the two Chinese companies received a total 34.4 million in total funding.[111] As with many aspects of AI, chip innovation is constantly occurring. For instance, Google recently launched a second-generation of TPUs, which Alphazero used to learn chess, that are able to train AI algorithms more efficiently than GPUs and CPUs.[112]

China's success in building supercomputers demonstrates its potential to catch-up to world leaders in AI hardware. One metric that demonstrates this finding is the share of the highest-performing supercomputers located in China, per the global Top500 list. In 2014, China's share of the Top500 list consisted of 76 systems (15.2%), which was a distant second to the U.S. at 232 systems (46.4%).[113] The June 2017 version of the Top500 list saw China nearly catch up to the U.S., with the former boasting 159 systems (31.8%) and the latter having 168 systems (33.6%).[114] Further distinctions can be made with respect to this category of hardware.. It is possible that supercomputing facilities can become more applicable in future AI development on a very large scale. Nevertheless, as noted by Larry Smarr, a physicist at the University of California, China's excellence in manufacturing traditional supercomputers may not matter as much if other countries develop new, more efficient supercomputers that are designed specifically for challenges like AI.[115]

In sum, China has relied on imports and acquisitions to boost the most immediately relevant aspects of AI hardware. As this strategy has come under more scrutiny by the U.S. and EU, China is promoting national

106 Li, 2017

107 Metz, 2017

108 Li, 2017

109 Boundaries between the uses of different chips are fuzzy. Some companies use GPUs to execute algorithms as well. The tendency is for AI companies to use GPUs to train algorithms, and use TPUs and FPGAs to execute algorithms.

110 Freund, 2017

111 The IT Juzi and Tencent Institute report does not specify the time range of these figures. Per author's check of the figures, they appear to refer to total money raised in all funding rounds since the company's launch.

112 Tung, 2017

113 HPCwire, 2014

114 Author's calculations from www.top500.org

115 Markoff, 2016

champions in its domestic chip-making industry and making long-term bets on powerful supercomputing facilities. In some respects, China's approach to building its domestic semiconductor industry is a microcosm for its overall approach to AI development. State-directed theft of intellectual property, targeted poaching of talent, and strong government guidance have all been part of China's brute force approach to boosting its semiconductor industry.[116] Yet despite this effort, China's domestic production of integrated circuits (IC) accounts for less than 13% of the country's demand, and its trade deficit in the global IC market has more than doubled since 2005.[117] Thus, catching up in the domain of AI hardware may take a long time, if it happens at all.

ii. Closed critical mass of data

Data is another important driver for AI systems because machine learning is notoriously data-hungry. Access to large quantities of data has been cited as one of the advantages for China's AI development.[118] With relatively lax privacy protections, Chinese technology giants collect vast troves of data, and sharing among government agencies and companies is common. Chinese consumers, the source of much of this data, are early and eager tech adopters, as reflected by smartphone penetration rates across the country and industry forecasts which show that the mainland will account for over 50% of the global retail e-commerce market by 2018.[119] Per a report by CCID Consulting, China is projected to possess 30% of the world's data by 2030.[120] President of the Chinese Academy of Sciences, Bai Chunli, estimated, "By 2020, China will hold 20% of the global data, which is expected to reach 44 trillion gigabytes."[121]

China's data protectionism is part of a broader trend toward digital protectionism in which China's internet is a closed ecosystem: in this world, the Chinese government censored and blocked Facebook and Google, thereby enabling the rise of domestic platforms like Wechat and Weibo. One can see the advantages of data protectionism for AI development. If data is a scarce resource for AI development, China could establish exclusive control over this resource for its companies and research institutes. On the other hand, if more and more data is shared across platforms and countries, other actors could benefit from global data sharing while China remains closed off.

iii. Algorithm development is high-quality but still lacking in fundamental innovation

Research and algorithm development is a critical factor for the advancement of AI. Chinese researchers are able to quickly replicate the most advanced algorithms developed anywhere in the world. Drawing from a domestic pool of talent, which includes the most STEM graduates out of any country in the world,[122] China has pumped out a large quantity of AI research, but still cannot match the leading countries in the most innovative

116 I thank Elsa Kania for this framing.

117 Ernst, 2016

118 The Economist, 2017b; The New York Times 2017

119 South China Morning Post, 2016

120 Kania, 2017b

121 Chinese Academy of Sciences, 2017

122 World Economic Forum, 2016

Table 4: AAAI Conference Presentations by Country

Year	USA	China	UK	Australia
2010	192 (55.2%)	42 (12.1%)	19 (5.5%)	20 (5.7%)
2011	195 (56.7%)	45 (13.1%)	18 (5.2%)	23 (6.7%)
2012	189 (49.3%)	50 (13.1%)	24 (6.3%)	35 (9.1%)
2013	156 (56.3%)	44 (15.9%)	11 (4.0%)	14 (5.1%)
2014	223 (47.0%)	104 (21.9%)	24 (5.1%)	31 (6.5%)
2015	**326 (48.4%)**	**138 (20.5%)**	**55 (8.2%)**	**59 (8.8%)**

Source: Japan's National Institute of Science and Technology Policy. National affiliation of each presentation determined by location of researchers' organization. Each co-author was counted once, so each presentation of findings could have resulted in more than one count recorded in the table (Koshiba et al. 2016).

research and the most talented researchers. In 2014, China surpassed the U.S. in the volume of AI research, as evidenced by metrics on AI-related patent registration and articles on deep learning,[123] which was noted in the Obama White House's strategic plan for AI research.[124] This is not a case of volume devoid of quality: data on presentations at the Association for the Advancement of Artificial Intelligence (AAAI) annual conference, widely recognized as a leading AI research conference, revealed that Chinese researchers accounted for over 20% of the findings presented, second only to those from the United States (Table 4).

However, China lags behind both the U.S. and UK in fundamental research, according to a McKinsey Global Institute report which found that U.S. and UK research is more influential by citation impact, as measured by the H-index.[125] When asked to compare the U.S. and Chinese AI strengths, Yann LeCun, director of Facebook's AI research, highlighted the importance of the top advanced AI research labs, which have been established in the U.S. (Google Brain, Facebook AI Research, OpenAI, and others).[126] Currently, both Chinese academics and companies tend to research applications of pre-existing AI technology; whether these two groups begin to adopt the "moonshot" mindsets that inspire the creation of new AI technologies will be a critical question for China's future AI research.[127]

The difference in fundamental AI research may also be partly due to a talent shortage. Despite the larger pool of STEM graduates, China has a talent pool of around 39,000 AI researchers, less than half of the size of the U.S. pool of over 78,000 researchers.[128] The U.S. benefits from having a large number of world-leading universities for AI research, as well as a more mature AI commercial ecosystem. This leads to more AI experts who have led multiple full cycles of projects. Nearly 50% of the AI researchers in the U.S. have more than 10 years of work

123 He, 2017

124 Zhang, 2017

125 McKinsey Global Institute, 2017a

126 Sixth Tone, 2017

127 Tse and Wang, 2017

128 Li, 2017; Studies have defined AI expertise in different ways. While Tencent's methodology focuses on employees at AI companies, others use job sites like Linkedin or authors of conference papers (Gagne et al., 2018).

experience, whereas only 25% in China have more than 10 years of work experience.[129]

iv. Partnership with the private AI sector

The last driver of AI development analyzed in this report is the commercial AI ecosystem. A range of indicators – measures of the number of AI companies and total AI financing received in particular - put China's AI commercial ecosystem as the second largest in the world, at around one quarter the size of its U.S. counterpart. Out of the total number of AI companies in the world (2542 according to data from June 2017), the US hosts 42% of them, while China ranks second with 23%.[130] The U.S. ecosystem nurtures more competitive AI startups, with 39 promising AI startups ranked by total funds raised from CB Insight's AI 100 list, compared to 3 promising Chinese AI startups.[131] In recent years, large tech companies have competed to acquire leading private AI companies for access to technology and expertise,[132] and U.S. tech giants have benefited directly from the robust AI startup scene in this respect. From 2012 to July of 2017, out of the 79 total acquisitions of AI companies, 66 were acquired by U.S. companies, while only 3 were acquired by Chinese companies (Baidu, in all three cases); relatedly, of the companies acquired in these M&A deals, only one was from China while 51 were from the states.[133]

While the number of AI firms provides a good first-cut measure of industry size, the amount of financing raised by AI firms can help provide a more comprehensive picture of the AI landscape. From 2012 to 2016, according to findings from a Wuzhen Institute report, Chinese AI firms received USD 2.6 billion in investment funding, significantly less than the USD 17.2 billion received by their American peers.[134] As was the case with the fuzzy distinction between "core AI" and "AI-related industries", numbers on the scale of the commercial AI sector are murky. For instance, another report from IT Juzi and Tencent Institute offers a markedly different estimation of the scale of AI financing for both the U.S. and China, finding that the U.S. receives 51.10% (USD 14.8 billion) of world's AI funding while Chinese AI companies rank second with 33.18% (USD 9.6 billion) of the world's AI funding.[135] Another factor behind conflicting estimates is the fast-changing nature of the AI scene. For reference, from 2014 to 2016, the number of new Chinese AI companies accounted for 55% of all Chinese AI companies ever established, and the scale of Chinese AI investment for those three years accounted for over 90% of the total Chinese financing that has ever been committed to AI.[136] In 2017, China's AI startup scene received 48% of funding going to AI startups globally, surpassing the equity funding share of U.S. AI startups , which received 38% of the global share.[137] The growth in China's AI scene just in the past year has been astronomical, as China accounted for only 11.3% of global funding in 2016. Though estimates differ with respect to the precise

129 Yang, 2017

130 Li, 2017

131 McKinsey Global Institute, 2017a

132 Examples include Google's acquisition of DeepMind, Intel's acquisition of Movidius, and Twitter's acquisition of image-processing startup Magic Pony.

133 Author's own calculations from https://www.cbinsights.com/research/top-acquirers-ai-startups-ma-timeline/.

134 The Economist, 2017b

135 The time range for these figures is unclear (Li, 2017).

136 Wuzhen Institute, 2017

137 CBInsights, 2018b

size of China's AI sector, across the full range of indicators considered in this section, China's AI industry has significantly increased in both absolute and relative terms in the past few years.

Across all drivers, it is important to note that these do not have to be viewed through the lens of zero-sum competition. In fact, in each driver, collaborations across countries are often mutually beneficial. China is a major market for U.S. AI hardware, data can be shared across borders, and researchers from around the world coauthor AI papers together. Lastly, cross-border AI investments, with respect to the U.S. and China, have significantly increased in the past few years. From 2016 to 2017, China-backed equity deals to U.S. startups rose from 19 to 31 and U.S.-backed equity deals to Chinese startups quadrupled from 5 to 20.[138] Moreover, what is often forgotten is the fact that both Tencent and Alibaba are multinational, public companies that are owned in significant portions by international stakeholders (Naspers has a 33.3% stake in Tencent and Yahoo has a 15 percent stake in Alibaba). In sum, while the next section offers a comparative assessment of the U.S. and China's AI capabilities, it is important to consider the interdependent, positive-sum aspects of various AI drivers.

B. Assessment of China's position on the AI Potential Index

In the course of evaluating the different components of China's AI strategy, this report has assessed China's AI capabilities across indicators associated with each of the four drivers. In an attempt to integrate these indicators, the report takes a first-cut at developing a measure of a country's AI power. The methodology will need to be refined, as this index is limited by proxy measures for which reliable data was collected for both the U.S. and China (Table 5).[139]

As Table 5 shows, China trails the U.S. in every driver except for access to data. According to the AI Potential Index, China's AI capabilities (AIPI = 17) are about half of those of America (33). This index is meant to be a rough-guess measure to assess the overall AI capabilities of any country as a fraction of total global AI capabilities, weighted by the level of importance of each driver (in the first iteration of this index, they are weighted equally). The proxies are not perfect by any means, and some aspects of each of these drivers (level of genius talents in research, the quality of the data, etc.) cannot be quantified.

The estimates are valuable for testing potential scenarios for China's AI development, since relative weights assigned to each driver can be adjusted, if one thinks that a particular driver is more important than another. For example, Baidu's Chief Operating Officer, Qi Lu, argues that China will be best positioned to leverage the potential of AI because he views data as the ultimate driver. For him, China's lead in data, the "primary means of production," would outweigh its deficits in the other drivers.[140] The AIPI can help clarify some of the parameters of Qi Lu's hypothesis. Assuming that the current proxy measures for each driver are relatively accurate, the

138 *Ibid.*

139 Since I was unable to find numbers for the share of world data controlled by the U.S. in 2020 and 2030 to compare to those I had for China, I substituted the number of mobile users as a proxy measure for the total data available to each country.

140 Qi Lu discusses China's comparative advantages in AI in the first 30 minutes of this interview with YCombinator: https://www.youtube.com/watch?v=WSydk0XzxEE.

Table 5: Metrics for Various Drivers in China's AI Development

Main Driver in AI	Proxy Measure(s)	China	USA
Hardware	Int'l market share of semiconductor prod. (2015)	4% of world	50% of world
	Financing for FPGA chip-makers (2017)	USD 34.4 million (7.6% of world)	USD 192.5 million (42.4% of world)
Data[a]	Mobile users (2016)[b]	1.4 billion (20.0% of world)	416.7 million (5.5% of world)
Research and Algorithms	Number of AI experts	39, 200 (13.1% of world)	78,700 (26.2% of world)
	Percentage of AAAI Conference Presentations (2015)[c]	20.5% of world	48.4% of world
Commercial AI Sector	Proportion of world's AI companies (2017)	23%	42%
	Total investments in AI companies (2012-2016)	USD 2.6 billion (6.6% of world)	USD 17.2 billion (43.4%)
	Total global equity funding to AI startups (2017)	48% of world	38% of world
AI Potential Index[d]	Avg. of the four avg. proxy measures[e]	(5.8 + 20 + 16.8 + 25.9)/4 = **17**	(46.2 + 5.5 + 37.3 +41.1)/4 = **33**

[a] A recent joint Sinovation and Eurasia Group report also used number of mobile users as a key indicator for data. This report went a step further and argued that China has even more of an advantage in data since Chinese consumers make 50 x as many mobile payments as Americans (Lee and Triolo, 2017). Other indicators that would further refine the data driver would include: data quality, integration capacity of different data holders (covered by a new government AI readiness index, available at: https://www.oxfordinsights.com/government-ai-readiness-index), and the degree to which data is bounded up in multinational companies based in a country (earlier questions of data pooling in the above section on the data driver come into play if U.S. or Chinese companies are able to pool data from global consumers). For the last point, U.S. companies have faced issues transferring European consumer data back to the states(Heide, 2016).

[b] World Bank 2016 data: https://data.worldbank.org/indicator/IT.CEL.SETS?locations=CN-US&name_desc=true

[c] Since the AI field is rapidly changing, the exclusion of years 2016 and 2017 in this proxy measure could mean that it doesn't accurately capture the current state of research in both countries. Other proxy measures are more recent.

[d] AI Potential Index is indexed from 0 to 100, with 100 representing one country being in complete control of AI technology.

[e] For the hardware and commercial AI drivers, within which I had multiple figures, I first took the average of of the different proxy measures to come up a single average score for each driver. Then I averaged the four driver scores to get the final AIPI measure.

relative importance of the data driver would have to be over four times that of each of the other three drivers for China's AIPI score to equal that of the United States.[141] Conversely, data may be less important in the future compared to other drivers, since future AI algorithms may not need as much pre-created data (e.g. simulation pipelines for training robots).[142] Other potential tests could incorporate countries' AIPI score from past years to project future trends in AIPI. As China continues to ramp up state support for AI, encourage AI tech and talent transfer, and make long-term bets on AI, the AIPI could serve as one of the tools to measure its progress.

141 Calculated by the following method. Let x be the "added importance factor." Then, multiple the data driver by x and divide every other driver by x. Set the two sums of proxy measures for the U.S. and China to be equal to each other. Solve for x, which comes out to around 2.29. This result means that the importance of all the drivers had to be divided by more than 2, and the relative importance of the data driver had to be multiplied by more than 2 for China's AIPI to achieve parity with the U.S. AIPI. Hence, the relative importance of the data driver would have to be over four times that of the other three drivers for this result to occur.

142 I thank Helen Toner for this point.

IV. CONSEQUENCES

In this final section, the report turns to the potential implications of China's AI strategy on four issue areas: AI standards and safety, national security, economic development, and social governance. It is outside of the scope of the report to fully assess the potential developments in all four areas. Instead, the thrust of this report is to show that all the pieces matter in China's AI development - that in the case of China's pursuit of AI, the how is key to unlocking the why. Toward that end, I focus in on how some of the key features of China's AI strategy factor into the longer-term implications in each of these four areas.

A. Emerging engagement in AI ethics and safety

As one of the leading countries in AI, China's approach to AI regulation will play an essential role in navigating the unique risks of AI technology, including risk scenarios involving artificial general intelligence and misuse of AI as outlined by experts in recent years.[143] The Chinese government outlined plans for AI safety measures for the first time in the State Council's AI plan. The document stated that by 2025, China will have initially established AI laws and regulations, ethical norms, and beginnings of AI security assessment and control capabilities; and by 2030, China will have constructed more comprehensive AI laws and regulations, as well as an ethical norms and policy system.[144] No further specifics were given, which fits in with what some have called opaque nature of Chinese discussion about the limits of ethical AI research.[145] At the Asilomar Conference on Beneficial AI 2017, out of more than 150 attendees, only one was working at a Chinese institution at the time (Andrew Ng, who has now left his role at Baidu). Additionally, of the 37 researchers and 45 scientific publications funded by the Future of Life Institute's AI Safety Research program, none of the research was conducted at a Chinese institution. Lastly, of the 3462 AI/robotics researchers who signed a Future of Life Institute open letter to ban autonomous weapons, only three were based at Chinese institutions (all were affiliated with the Chinese University of Hong Kong).[146] Overall, China seems to have a low level of engagement with Western countries and institutions on discussions of AI safety across private, public, and academic sectors.[147]

However, there are promising signs of substantive engagement with issues of AI ethics and safety in China. A book published in November 2017, titled Artificial Intelligence: A National Strategic Initiative for Artificial Intelligence includes an important chapter that discusses the Asilomar AI Principles in detail and call for "strong regulations" and "controlling spells" for AI.[148] A wide range of Chinese AI researchers are also involved with translating the IEEE's Ethically Aligned Design report, as part of the Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems.

143 Bostrom, 2014; Brundage et al. 2018

144 State Council, 2017a

145 The Economist, 2017b

146 For a full list of the Future of Life Institute open letter signees see: https://futureoflife.org/awos-signatories/.

147 I thank Brian Tse for these points on AI safety

148 These terms are from my translations of the book, which are available upon request (Tencent Research Institute et al. 2017).

There are a variety of perspectives on AI safety and ethics in the Chinese AI community. Doubling as a launch event for the aforementioned book, the CAICT hosted a seminar in November 2017 on the unique challenges AI poses for law and governance.[149] Attendees included representatives from the Supreme People's Court, Weixing Shen, dean of Tsinghua University law school, and Si Xiao, Tencent's Chief Research Officer. From the readout of the conference, it appears that participants offered robust and, often differing, views on how to govern AI development. For instance, Dean Shen stated that AI development was an immutable social trend that should be embraced rather than excessively worried over, whereas Guobin Li, president of the Beijing Research Institute for Communication Law, argued that scholars should proactively address the legal and policy issues that could arise from AI.[150] The growing efforts of Chinese scholars to tackle difficult questions of AI governance means that assessing the relative influence of these different opinions on China's AI development will be an important endeavor.

Finally, AI may be the first technology domain in which China successfully becomes the international standard-setter. In another chapter, the book's co-authors, Tencent researchers and CAICT academics, linked Chinese leadership on AI ethics and safety as a way for China to seize the strategic high ground. They wrote, "China should also actively construct the guidelines of AI ethics, play a leading role in promoting inclusive and beneficial development of AI. In addition, we should actively explore ways to go from being a follower to being a leader in areas such as AI legislation and regulation, education and personnel training, and responding to issues with AI [emphasis mine]."[151] One important indicator of China's ambitions in shaping AI standards is the case of the International Organization for Standardization / International Electrotechnical Commission (ISO/IEC) Joint Technical Committee (JTC), one of the largest and most prolific technical committees in the international standardization, which recently formed a special committee on AI. The chair of this new committee is Wael Diab, a senior director at Huawei, and the committee's first meeting will be held in April 2018 in Beijing, China - both the chair position and first meeting were hotly contested affairs that ultimately went China's way.[152]

B. Tracking the potential of AI as a revolution in military affairs

Media reports of an AI arms race between the U.S. and China have proliferated in 2017,[153] and leading thinkers have identified AI as a technology that could provide a decisive strategic advantage in the international security realm.[154] In contrast, much of the Chinese academic literature discussing military possibilities for AI technology has been largely abstract and speculative, and a majority of it references or focuses on the U.S. Defense Advanced Research Projects Agency's activities.[155] Chinese military institutions, such as the NUDT, have increased their research efforts on intelligent robotics.[156] In the short-term, the People's Liberation Army (PLA) will likely

149 Science.china [kexue zhongguo]

150 *Ibid.*

151 These quote is from my translation of of the book, which are available upon request (Tencent Research Institute et al., 2017).

152 According to the author's conversation with a source knowledgeable about the discussions of the committee

153 The Economist, 2017b; New York Times, 2017b; New York Times, 2017c

154 Kaspersen, 2016

155 Kania, 2017c

156 Ray et al., 2016

continue to adopt a range of unmanned vehicles into all four services (Army, Navy, Air Force, and Rocket Force).[157] Combined with breakthroughs in UAV swarming and intelligentized missiles, these developments could challenge the U.S. military presence in the Pacific theater.

In the long-term, China's AI development could revolutionize its conduct of military affairs. Although material evidence for Chinese militarization of AI is limited, some rhetorical evidence does show that China sees AI as a revolutionary military technology. In a statement on the central government's work report by Lieutenant General Liu Guozhi, director of the Central Military Commission's Science and Technology Commission, he states, in reference to military applications of AI, that the world is "on the eve of a new scientific and technological revolution," and "whoever doesn't disrupt will be disrupted!"[158] Combined with AI's dual-use nature, China's high degree of civil-military fusion has raised concerns about the military applications of AI. Li Deyi, as a quintessential example, is both the director of the Chinese Association for Artificial Intelligence and a major general in the PLA.[159] To emphasize, many of these projections are largely speculative as the most sensitive military AI applications are not publicly disclosed. There is not a coherent consensus of ideas on AI in warfare within the PLA. Moreover, the influence of the PLA is not overwhelming, as other bureaucratic entities often have diverging views and the central party apparatus possesses final decision-making powers.

The degree to which China's militarization will constitute a revolution in military affairs is an important question. Drawing from Chinese-language, open-source articles by military scholars, a recent report by Elsa Kania, at the Center for a New American Security (CNAS), argues that the Chinese People's Liberation Army (PLA) views AI as a "trump card" technology that could revolutionize the conduct of future warfare.[160] As the CNAS report acknowledges, the thinking of the PLA and the central government on the direction of military AI is not solidified. Evidence from the PLA's investment in UAV swarming and intelligentized missiles shows that the most immediate applications of military AI could align with more limited, defensive goals, including asymmetric countering of U.S. military superiority in the Western Pacific and protecting China's nuclear deterrent.[161]

C. Economy benefits as a driving force

The implications of China's AI strategy in the economic realm are numerous. Research from PwC in 2017 estimated that China had the most to gain from AI technologies, forecasting a potential 26% boost in GDP to benefits from AI.[162] A report from McKinsey Global Institute supports this view, estimating that 51% of work activities in China can be automated - more than any other country in the world.[163] Faced with unfavorable demographic trends, China could improve its productivity levels by integrating AI systems.[164] This would enable

157 *Ibid.*
158 Kania, 2017c
159 Kania, 2017a
160 Kania, 2017d
161 Ray et al., 2016
162 South China Morning Post, 2017
163 McKinsey Global Institute, 2017a
164 *Ibid.*

China to sustain its economic growth and meet GDP targets. The stakes for global economic preeminence are stark. A report by PwC projects that the AI sector could contribute up to USD 15.7 trillion to the world economy by 2030.[165]

Economic benefit is the primary, immediate driving force behind China's development of AI, so evaluating the economic impact of China's AI strategy will be a key test of the strategy's feasibility and success. Early signs support cautious optimism about China's AI sector. Metrics from the section on China's commercial AI ecosystem revealed that new AI companies and investment in the years 2014-2016 surpassed the number of companies and investment in all the years prior. These figures should be tempered by the potential for speculative over-investment to cause boom-bust cycles and the need for more concrete figures directly tied to economic growth, such as revenues and assets. As earlier analysis on megaprojects demonstrated, China's industrial policy approach to scientific innovation has been criticized for diverting resources from bottom-up, investigator-driven projects to large national projects run by mediocre laboratories, on the basis of personal connections.

D. Implications of AI for China's mode of social governance

The State Council report acknowledges that the government will have to deal with some of the social aftershocks of AI's economic implications. Concretely, AI could accelerate the "digital divide" by placing a premium on high-skilled workers and reducing the demand for low-skilled workers whose jobs would be most at risk of being automated.[166] This may widen many of the divisions in Chinese society, including income inequality, gender inequality, and the urban/rural and coastal/inland opportunity gaps. At the same time, China is exploring the use of AI to predict evidence of social unrest before it coalesces.[167] For instance, in the same section, the State Council states that AI will also play an "irreplaceable" (不可替代) role in maintaining social stability. Toward that end, China aims to integrate AI across a broad range of public services, including judicial services, medical care, and public security. Already, Shanghai is piloting an AI system that reviews the validity of evidence in criminal cases.[168] Moreover, Chinese government officials have praised AI's value for predictive policing measures, an approach that some scholars label "Digital Leninism."[169] AI techniques may also help Chinese censors find patterns in massive amounts of communication data.[170]

At the center of many of these AI-enabled forces is the Chinese government's planned "social credit system." The proposed system would constantly monitor and evaluate the activities of each Chinese citizen and rank his or her level of trustworthiness.[171] Moreover, the trust score would affect one's eligibility for a mortgage,

165 PwC, 2017
166 McKinsey Global Institute, 2017a
167 For more on this subject, See: Hoffman, 2017
168 Chen, 2017
169 Brown, 2017; Creemers, 2017
170 Economist, 2017a
171 Botswan, 2017

one's chances of getting a job, and the school placements of one's children. Advances in AI could automate the collection, management, and effective analysis of massive amounts of citizen data. China's Ministry of Public Security (MPS) is reportedly building the world's largest facial recognition database and is experimenting with expansive surveillance techniques in Xinjiang, a particularly volatile region of the country.[172] Although several local pilot projects are operational, national implementation is still in the early stages and is dependent on support from private companies' technological expertise.[173] Moreover, the consolidation of privacy protections in national-level standards and laws, mentioned earlier in the report, could forestall various social credit schemes. Regardless, the intersection between AI technologies and China's social governance is worthy of close attention.

Undoubtedly, the relevance of AI to China's core interests and China's receptiveness to issues of AI ethics and safety will have global consequences. China's AI strategy could spark military competition over a new strategic technology. At an event organized by the Center for a New American Security, former Deputy Defense Secretary Bob Work and the former executive chairman of Alphabet, Eric Schmidt, both urged the U.S. government to respond to China's national AI plan with a strategy of its own.[174] In fact, a reference to China winning the "algorithm battles" even made its way into a National Security Council memo, on the seemingly unrelated subject of centralizing the 5G network, for President Donald Trump.[175] China's AI dream could also affect who sits at the center of the international economic order. In the social governance realm, China's AI development could provide a model of "robust authoritarianism" that might appeal to other nations. At the same time, China could also beneficially contribute to peaceful governance and ethical norms for AI technologies. A clear-eyed assessment of its AI strategy is essential to deciphering how China will realize its AI dream.

172 Kania, 2017e

173 Ohlberg, 2017

174 Clark, 2017

175 Swan, 2018

REFERENCES

AI Impacts. "2016 Expert Survey on Progress in AI." December 14, 2016. Accessed December 07, 2017. https://aiimpacts.org/2016-expert-survey-on-progress-in-ai/#Answers-6.

Allen, Gregory, and Elsa B. Kania. "China Is Using America's Own Plan to Dominate the Future of Artificial Intelligence." Foreign Policy. September 08, 2017. Accessed December 06, 2017. http://foreignpolicy.com/2017/09/08/china-is-using-americas-own-plan-to-dominate-the-future-of-artificial-intelligence/.

Ball, Philip. "China's great leap forward in science." The Observer. February 18, 2018. Accessed February 22, 2018. https://www.theguardian.com/science/2018/feb/18/china-great-leap-forward-science-research-innovation-investment-5g-genetics-quantum-internet.

Bitzinger and Raska, M., Capacity for Innovation: Technological Drivers of China's Future Military Modernization. The Chinese People's Liberation Army in 2025. 2015. pp.129-61.

Bloomberg. "China Inc. Goes on a Buying Spree for Global Health Assets." July 05, 2016. Accessed February 22, 2018. https://www.bloomberg.com/news/articles/2016-07-05/china-inc-goes-on-a-buying-spree-for-global-health-care-assets.

Bloomberg. "China Biotech Promise Struggles to Keep Foreign Innovators." October 19, 2017. Accessed February 22, 2018. https://www.bloomberg.com/news/articles/2017-10-19/china-s-biotech-promise-is-struggling-to-keep-foreign-innovators.

Borowiec, Steven. "AlphaGo seals 4-1 victory over Go grandmaster Lee Sedol." The Guardian. March 15, 2016. Accessed December 06, 2017. https://www.theguardian.com/technology/2016/mar/15/googles-alphago-seals-4-1-victory-over-grandmaster-lee-sedol.

Bostrom. 2014. Superintelligence: Paths, Dangers, Strategies. Oxford: Oxford University Press.

Botsman, Rachel. "Big data meets Big Brother as China moves to rate its citizens." WIRED. November 28, 2017. Accessed December 07, 2017. http://www.wired.co.uk/article/chinese-government-social-credit-score-privacy-invasion.

Browne, Andrew. "China Uses 'Digital Leninism' to Manage Economy and Monitor Citizens." Wall Street Journal. October 17, 2017. Accessed December 8, 2017. https://www.wsj.com/articles/xi-jinping-leads-china-into-big-data-dictatorship-1508237820

Brundage, Miles. "Modeling Progress in AI." 2016.

Brundage et al. The Malicious Use of Artificial Intelligence: Forecasting, Prevention, and Mitigation. 2018. https://maliciousaireport.com.

Cao, C., 2008. China's brain drain at the high end: why government policies have failed to attract first-rate academics to return. Asian Population Studies, 4(3), pp.331-345

Cao, C., Suttmeier, R.P. and Simon, D.F., 2006. China's 15-year science and technology plan. Physics today, 59(12), p.38.

CB Insights. "Top AI Trends to Watch in 2018." 2018. https://www.cbinsights.com/research/report/artificial-intelligence-trends-2018/.

CB Insights Research. "The 10 Most Well-Funded Startups Developing Core Artificial Intelligence Tech." June 07, 2017. Accessed December 06, 2017. https://www.cbinsights.com/research/most-well-funded-artificial-intelligence-companies/.

Chen, Ziyan. "AI takes a look at legal evidence." China Daily. July 11, 2017. Accessed December 7, 2017. http://www.chinadaily.com.cn/china/2017-07/11/content_30064693.htm.

China Economic Net. "New Generation Artificial Intelligence Megaproject Implementation." [新一代人工智能重大项目启动]. November, 16, 2017, http://www.ce.cn/xwzx/gnsz/gdxw/201711/16/t20171116_26873888.shtml

China Military Science Editorial Department [zhongguo junshi kexue bianjibu]. "A Summary of the Workshop on the Game between AlphaGo and Lee Sedol and the Intelligentization of Military Command and Decision-Making" [围棋人机大战与军事指挥决策智能化研讨会观点综述], China Military Science [中国军事科学], April 2, 2016.

Chinese Academy of Sciences. "China's AI Business Ready to Lead the World." June 2017. Accessed December 07, 2017. http://english.cas.cn/newsroom/news/201706/t20170602_177674.shtml.

Clark, C., 2017. Our Artificial Intelligence 'Sputnik Moment' Is Now: Eric Schmidt & Bob Work. Breaking Defense. November 1, 2017. Accessed February 7, 2018. https://breakingdefense.com/2017/11/our-artificial-intelligence-sputnik-moment-is-now-eric-schmidt-bob-work

Clover, Charles and Ju, Sherry. "China tech groups to share data with state in online fraud battle." October 26, 2016. Accessed December 7, 2017. https://www.ft.com/content/4ebc5fb6-9a70-11e6-8f9b-70e3cabccfae.

Council on Foreign Relations. "Beijing's AI Strategy: Old-School Central Planning with a Futuristic Twist." Accessed December 06, 2017. https://www.cfr.org/blog/beijings-ai-strategy-old-school-central-planning-futuristic-twist.

Costello, John. "Chinese Efforts in Quantum Information Science: Drivers, Milestones, and Strategic Implications." Testimony for the U.S.-China Economic and Security Review Commission. March 16, 2017. https://www.uscc.gov/sites/default/files/John%20Costello_Written%20Testimony_Final2.pdf

Creemers, R., 2017. Cyber-Leninism: The Political Culture of the Chinese Internet. Speech and Society: Comparative Perspectives, p.255.

Cronin, Beau. "The dynamic forces shaping AI." O'Reilly Media. July 06, 2016. Accessed December 07, 2017. https://www.oreilly.com/ideas/the-four-dynamic-forces-shaping-ai.

Deepmind. "The Story of AlphaGo So Far." Accessed December 28, 2017. https://deepmind.com/research/alphago/.

Donnan, Shawn. "Trump Blocks US Chipmaker's Sale to China-backed Buyer." September 14, 2017. Accessed December 07, 2017. https://www.ft.com/content/d2924226-98ce-11e7-a652-cde3f882dd7b

dwnews [中国-多维新闻网]. "Full Text of Xi Jinping Report to 19th Congress," [习近平十九大报告全文]. October 18, 2017. Accessed December 06, 2017. http://news.dwnews.com/china/news/2017-10-18/60018047_all.html.

Economic Daily. "Innovate, lead development, and build a science and technology superpower - specialists in science and technology study and implement the spirit of the 19th CPC National Congress." [创新引领发展 建设科技强国——科技专家学习贯彻党的十九大精神]. November 3, 2017. Accessed February 6, 2018. http://cpc.people.com.cn/n1/2017/1103/c415067-29625761.html.

Ernst, Dieter. "China's Bold Strategy for Semiconductors - Zero-sum Game or Catalyst for Cooperation?" East-West Center Working Papers. September 2016. https://www.eastwestcenter.org/system/tdf/private/iegwp009.pdf?file=1&type=node&id=35798.

Feigenbaum, Evan A. "The Deep Roots and Long Branches of Chinese Technonationalism." Carnegie Endowment for International Peace. August 12, 2017. Accessed February 22, 2018. http://carnegieendowment.org/2017/08/12/deep-roots-and-long-branches-of-chinese-technonationalism-pub-72815.

Feng, Emily. "Chinese tech groups display closer ties with Communist party." Financial Times. October 10, 2017. Accessed December 7, 2017. https://www.ft.com/content/6bc839c0-ace6-11e7-aab9-abaa44b1e130.

Fischer, Sophie-Charlotte. 2017. "CFIUS in US-China Relations and the Case of AI." Future of Humanity Institute Backgrounder.

Freund, Karl. "Will ASIC Chips Become The Next Big Thing In AI?" Forbes. August 08, 2017. Accessed March 01, 2018. https://www.forbes.com/sites/moorinsights/2017/08/04/will-asic-chips-become-the-next-big-thing-in-ai/#4a8ab7a311d9.

Gagne et al. "Global AI Talent Report 2018." Element AI. February 7, 2018. Accessed February 15, 2018. www.jfgagne.ai/talent/;

Giles, Martin. "The Race to Power AI's Silicon Brains." MIT Technology Review. November 20, 2017. Accessed February 15, 2017. https://www.technologyreview.com/s/609471/the-race-to-power-ais-silicon-brains/

GYZ Holdings. "Development Trends and New Changes in Chinese Government Guidance Funds" [中国政府引导基金发展新趋势、新变化]. 2017. http://www2.gyzim.com/site/about?id=2576.

Harbringer. "A Cross Border Perspective on Frontier Tech Investing - With Linear Venture Founding Partner Harry Wang." October 30, 2017. Accessed December 07, 2017. http://www.theharbingerchina.com/blog/a-cross-border-perspective-on-frontier-tech-investing-with-linear-venture.

He, Yujia. 2017. How China is preparing for an AI-powered Future. Wilson Briefs. https://www.wilsoncenter.org/sites/default/files/how_china_is_preparing_for_ai_powered_future.pdf

Heide, Dana. "Multinational Companies Remain Wary of U.S.-EU Data-Transfer Pact; Survey shows many are relying on contract provisions Europe's highest court could invalidate." Wall Street Journal. September 6, 2016.

Hern, Alex. "China censored Google's AlphaGo match against world's best Go player." The Guardian. May 24, 2017. Accessed December 06, 2017. https://www.theguardian.com/technology/2017/may/24/china-censored-googles-alphago-match-against-worlds-best-go-player.

Hoffman, Samantha. "Programming China: The Communist Party's autonomic approach to managing state security." MERICS China Monitor. December 12, 2017 https://www.merics.org/sites/default/files/2017-12/171212_China_Monitor_44_Programming_China_EN__0.pdf

HPCwire. "China's Supercomputing Strategy Called Out." July 18, 2014. Accessed December 07, 2017. https://www.hpcwire.com/2014/07/17/dd/.

Huang, J. and Wang, Q., 2003. Agricultural biotechnology development and policy in China.

iiMedia [艾媒咨询权威."2017 China Artificial Intelligence Industry Special Research Report" [2017年中国人工智能产业专题研究报告]. April 6, 2017. Accessed December 9, 2017. http://www.sohu.com/a/132360429_468646

Inkster, N., 2016. China's Cyber Power. Routledge. Available online at: https://www.iiss.org/en/publications/adelphi/by%20year/2016-d199/china--39-s-cyber-power-f1db/ap456-05-chapter-3-6229.

International Trade Administration. "2016 Top Markets Report Semiconductors and Related Equipment." July 2016. https://www.trade.gov/topmarkets/pdf/Semiconductors_Top_Markets_Report.pdf

Jing, Meng, and Dai, Sarah. "China Recruits Baidu, Alibaba, and Tencent to AI 'national team'." South China MOrning Post. November 21, 2017. Accessed December 29, 2017. http://www.scmp.com/tech/china-tech/article/2120913/china-recruits-baidu-alibaba-and-tencent-ai-national-team

John, A., 2017. Europe seeks to restrict Chinese investment. South China Morning Post. Accessed February 6, 2018. http://www.scmp.com/business/companies/article/2111074/european-commission-seeks-restrict-investment-chinese-companies.

Kania, Elsa(a). Testimony before the U.S.-China Economic and Security Review Commission: Chinese Advances in Unmanned Systems and the Military Applications of Artificial Intelligence—the PLA's Trajectory towards Unmanned, "Intelligentized" Warfare," U.S.-China Economic and Security Review Commission. February 23, 2017. https://www.uscc.gov/sites/default/files/Kania_Testimony.pdf.

Kania, Elsa(b). Beyond CFIUS: The Strategic Challenge of China's Rise in Artificial Intelligence. Lawfare. 2017. Accessed February 6, 2018. https://www.lawfareblog.com/beyond-cfius-strategic-challenge-chinas-rise-artificial-intelligence.

Kania, Elsa (c). "数字化 – 网络化 – 智能化: China's Quest for an AI Revolution in Warfare." The Strategy Bridge. June 08, 2017. Accessed December 07, 2017. https://thestrategybridge.org/the-bridge/2017/6/8/-chinas-quest-for-an-ai-revolution-in-warfare#_edn23.

Kania, Elsa (d). "Battlefield Singularity: Artificial Intelligence, Military Revolution, and China's Future Military Power. November 2017. Center for a New American Security. Retrieved: https://s3.amazonaws.com/files.cnas.org/documents/Battlefield-Singularity_Nov-2017.compressed.pdf?mtime=20171127155819.

Kania, Elsa (e). "Seeking a Panacea: the Party-State's Plans for Artificial Intelligence (Part 2)." Party Watch Initiative. November 16, 2017. Accessed December 07, 2017. https://www.ccpwatch.org/single-post/2017/11/15/Seeking-a-Panacea-the-Party-State%E2%80%99s-Plans-for-Artificial-Intelligence-Part-2?platform=hootsuite.

Kaspersen, Anja. 2016. "We're on the brink of an artificial intelligence arms race. But we can curb it." World Economic Forum. Accessed February 6, 2018. https://www.weforum.org/agenda/2016/06/should-we-embrace-the-rise-of-killer-robots/

Koshiba et al. "Research Trends of AI based on International/National Conferences Proceedings." [国際・国内会議録の簡易分析に基づく我が国の人工知能研究動向把握の試み]. National Institute of Science and Technology Policy. August 2016. http://hdl.handle.net/11035/3152.

Lee, Kai-fu, and Paul Triolo. "AI in China: Cutting Through the Hype." Sinovation and Eurasia Group Geo-Tech Team." December 6, 2017. https://www.eurasiagroup.net/live-post/ai-in-china-cutting-through-the-hype.

Li, Jingwang. 2017. 2017 China-US AI Venture Capital State and Trends Research Report. IT Juzi and Tencent Institute. Full report in Chinese can be found here: http://voice.itjuzi.com/?p=16960.

Lucas, L. & Feng, E., 2017. "China's push to become a tech superpower triggers alarms abroad." Financial Times. March 19, 2017. Accessed February 7, 2018. https://www.ft.com/content/1d815944-f1da-11e6-8758-6876151821a6

Lucas, Louise. "Alibaba to invest $15bn in R&D labs in push to become AI leader." Financial Times. October 11, 2017. Accessed February 22, 2018. https://www.ft.com/content/ac3fd8f8-ae5f-11e7-beba-5521c713abf4.

Markoff, J., 2016. China Wins New Bragging Rights in Supercomputers. The New York Times. Accessed February 7, 2018. https://www.nytimes.com/2016/06/21/technology/china-tops-list-of-fastest-computers-again.html.

Martin, Peter. "The Humbling of the NDRC: China's National Development and Reform Commission Searches for a New Role Amid Restructuring." Jamestown. March 06, 2014. Accessed February 23, 2018. https://jamestown.org/program/the-humbling-of-the-ndrc-chinas-national-development-and-reform-commission-searches-for-a-new-role-amid-restructuring/.

McGregor, J., 2010. "China's drive for 'indigenous innovation'." Global Regulatory Cooperation Project and US Chamber of Commerce. http://www. uschamber. com/sites/default/files/reports/100728chinareport_0.pdf.

McKinsey Global Institute(a). Artificial Intelligence: Implications for China. April 2017. Discussion Paper Presented at the 2017 China Development Forum.

McKinsey Global Institute(b). Artificial Intelligence The Next Digital Frontier. June 2017. Discussion Paper. Pg. 6.

Metz, Cade. "How AI Is Shaking Up the Chip Market." Wired. June 03, 2017. Accessed December 07, 2017. https://www.wired.com/2016/10/ai-changing-market-computer-chips/.

Mozur, Paul. "Beijing Wants A.I. to Be Made in China by 2030." The New York Times. July 20, 2017. Accessed December 06, 2017. https://www.nytimes.com/2017/07/20/business/china-artificial-intelligence.html.

New Intellectual Report [新智元报道]. "China Academy of Engineering: Unveiling of Artificial Intelligence 2.0 Era" [中国工程院院刊：人工智能2.0时代序幕开启]. February 21, 2017. http://www.sohu.com/a/126825406_473283.

New York Times. 2017. "China Gains on the U.S. in the Artificial Intelligence Arms Race" https://cn.nytimes.com/world/20170204/artificial-intelligence-china-united-states/en-us/.

"Notice on the 13th Five Year Plan for Developing National Strategic and Emerging Industries (2016-2020)" [国务院关于印发"十三五"国家战略性新兴产业发展规划的通知], State Council, November 29, 2016, http://www.gov.cn/zhengce/content/2016-12/19/content_5150090.htm.

Ohlberg et al. "Central Planning, Local Experiments: the complex implementation of China's Social Credit System." MERICS China Monitor. December 12, 2017. https://www.merics.org/sites/default/files/2017-12/171212_China_Monitor_43_Social_Credit_System_Implementation.pdf

Orr, Gordon and Thomas, Christopher. "Semiconductors in China: Brave new world or same old story?" McKinsey & Company. August 2014. Accessed December 07, 2017. https://www.mckinsey.com/industries/semiconductors/our-insights/semiconductors-in-china-brave-new-world-or-same-old-story.

Philippidis, Alex. "BGI Genomics Raises $81M in IPO." GEN. July 17, 2017. Accessed February 22, 2018. https://www.genengnews.com/gen-news-highlights/bgi-genomics-raises-81m-in-ipo/81254663.

PwC. "Sizing the Prize." 2017. https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf

President's Council of Advisors on Science and Technology. "Ensuring Long-Term U.S. Leadership in Semiconductors." Report to the Executive Office of the President. January 2017. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_ensuring_long-term_us_leadership_in_semiconductors.pdf

Ray, Jonathan, Katie Atha, Edward Francis, Caleb Dependahl, Dr. James Mulvenon, Daniel Alderman, and Leigh Ann Ragland-Luce, "China's Industrial and Military Robotics Development," Defense Group Inc., Research Report Prepared on Behalf of the U.S.-China Economic and Security Review Commission, October 2016, https://www.uscc.gov/sites/default/files/Research/DGI_China%27s%20Industrial%20and%20Military%20 Robotics%20Development.pdf

Sacks, Samm. "New China Data Privacy Standard Looks More Far-Reaching than GDPR." New China Data Privacy Standard Looks More Far-Reaching than GDPR | Center for Strategic and International Studies. January 29, 2018. Accessed February 22, 2018. https://www.csis.org/analysis/new-china-data-privacy-standard-looks-more-far-reaching-gdpr.

Schiermeier, Quirin. "China: At a crossroads." Nature News. March 05, 2014. Accessed December 07, 2017. https://www.nature.com/naturejobs/science/articles/10.1038/nj7490-129a.

Science.china [kexue zhongguo]. "Artificial Intelligence' Book Conference and Artificial Intelligence Legal Seminar Held in Beijing." [《人工智能》新书发布会暨人工智能法律研讨会在京举行]. November 22, 2017. Accessed February 15, 2018. http://science.china.com.cn/2017-11/22/content_40077843.htm.

Simonite, Tom. "China Targets Nvidia's Hold on Artificial Intelligence Chips." Wired. November 20, 2017. Accessed December 07, 2017. https://www.wired.com/story/china-challenges-nvidias-hold-on-artificial-intelligence-chips/.. I thank Sophie-Charlotte Fisher for this point.

Sixth Tone. "Facebook AI Exec: China Lags Behind US Due to Lack of Top Labs." March 24, 2017. Accessed December 07, 2017. http://www.sixthtone.com/news/2109/facebook-director-ai-china-lacks-talent-compete.

South China Morning Post. "China leads Asian consumption of technology." May 24, 2016. Accessed December 07, 2017. http://www.scmp.com/tech/china-tech/article/1945563/china-leads-asian-consumption-technology. I thank Sophie-Charlotte Fischer for this point.

South China Morning Post. "China scours the globe for talent in artificial intelligence, big data." November 22, 2017. Accessed December 07, 2017. http://www.scmp.com/tech/innovation/article/2118276/artificial-intelligence-and-big-data-will-be-growth-drivers-chinas.

Springut, M., Schlaikjer, S. and Chen, D., 2011. China's Program for Science and Technology Modernization: Implications for American Competitiveness: Prepared for the US-China Economic and Security Review Commission. CENTRA Technology.

State Council(a). "State Council Notice on the New Generation Artificial Intelligence Development Plan" [国务院关于印发新一代人工智能发展规划的通知]. July 8, 2017. http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm.

State Council (b). "Govt Work Report turns 'artificial intelligence' into buzzword." March 12, 2017. Accessed December 06, 2017. http://english.gov.cn/premier/news/2017/03/12/content_281475592727661.htm.

Swan et al. "Scoop: Trump Team Considers Nationalizing 5G Network." Axios. January 28, 2018. Accessed February 4, 2018. https://www.axios.com/trump-team-debates-nationalizing-5g-network-f1e92a49-60f2-4e3e-acd4-f3eb03d910ff.html

The Economist (a). Why China's AI Push is Worrying. 2017. https://www.economist.com/news/leaders/21725561-state-controlled-corporations-are-developing-powerful-artificial-intelligence-why-chinas-ai-push&num=1&hl=en&gl=uk&strip=1&vwsrc=0.

The Economist (b). 2017. "China may match or beat America in AI." https://www.economist.com/news/business/21725018-its-deep-pool-data-may-let-it-lead-artificial-intelligence-china-may-match-or-beat-america.

Tencent Research Institute, China Academy of Information and Communications Technology, Tencent AI Lab, and Tencent Open Platform. Artificial Intelligence: A National Strategic Initiative for Artificial Intelligence [人工智能：国家人工智能战略行动抓手]. China Renmin University Press: 2017. ["Chapter 23: 23 'Strong Regulations' for AI," "Chapter 13: Top-level Plans"].

Tomson, Iain. "US govt bans Intel from selling chips to China's supercomputer boffins." The Register. April 10, 2015. Accessed March 01, 2018. https://www.theregister.co.uk/2015/04/10/us_intel_china_ban/.

Tse, Edward, and Jackie Wang. "How China's AI experts can beat Google and Microsoft by 2030." South China Morning Post. August 27, 2017. Accessed February 22, 2018. http://www.scmp.com/comment/insight-opinion/article/2108318/how-chinas-ai-experts-can-beat-google-and-microsoft-their.

Tung, L., 2017. GPU killer: Google reveals just how powerful its TPU2 chip really is. ZDNet. Accessed February 6, 2018. http://www.zdnet.com/article/gpu-killer-google-reveals-just-how-powerful-its-tpu2-chip-really-is/

Vincent, James. "Chinese supercomputer is the world's fastest - and without using US chips." The Verge. June 20, 2016. Accessed December 07, 2017. https://www.theverge.com/2016/6/20/11975356/chinese-supercomputer-worlds-fastes-taihulight.

Vincent, James. "Huawei takes a swipe at Apple, promises to unveil 'The Real AI Phone' next month." The Verge. September 18, 2017. Accessed February 22, 2018. https://www.theverge.com/circuitbreaker/2017/9/18/16325022/huawei-real-ai-phone-mate-10.

Weinland, Don. "China Uses Investment Funds to Lead Reform Push." Financial Times. July 16, 2017. Accessed December 07, 2017. https://www.ft.com/content/528b242e-66f3-11e7-8526-7b38dcaef614.

Wood, Peter. "Chinese Perceptions of the." Jamestown. October 04, 2016. Accessed December 06, 2017. https://jamestown.org/program/chinese-perceptions-third-offset-strategy/.

World Economic Forum. 2016. The Human Capital Report 2016. http://reports.weforum.org/human-capital-report-2016/measuring-human-capital/?doing_wp_cron=1486038808.8636078834533691406250.

Wübbeke et al. 2016. Made in China 2025: The making of a high-tech superpower and consequences for industrial countries. Mercator Institute for China Studies. https://www.merics.org/en/papers-on-china/made-china-2025.

Wuzhen Institute. 2017. Global AI Development Report (Framework Document). A full pdf of this report is available upon request.

Xiang, Nina. "Can China's $383B Government Guidance Funds Help Turn It Into An Innovative Nation?" China Money Network. December 08, 2016. Accessed December 07, 2017. https://www.chinamoneynetwork.com/2016/09/05/can-chinas-383b-government-guidance-funds-help-turn-it-into-an-innovative-nation.

Yang, Qingqing. "Ceiling hit by search model, Baidu uplifts AI strategy with new CEO." [搜索模式面临天花板 百度总裁换帅升级人工智能战略]. 21st Century Business Herald. [21世纪经济报道]. January 18, 2017. http://epaper.21jingji.com/html/2017-01/18/content_54928.htm.

Yang, Yuan. "China Fuels Boom in Domestic Tech Start-ups." Financial Times. October 21, 2017. Accessed December 7, 2017. https://www.ft.com/content/b63ee746-afc6-11e7-aab9-abaa44b1e130.

Yuan, Li. "Beijing Pushes for a Direct Hand in China's Big Tech Firms." The Wall Street Journal. October 11, 2017. Accessed December 07, 2017. https://www.wsj.com/articles/beijing-pushes-for-a-direct-hand-in-chinas-big-tech-firms-1507758314.

Zhang, Sarah. "China's Artificial-Intelligence Boom." The Atlantic. February 16, 2017. Accessed December 07, 2017. https://www.theatlantic.com/technology/archive/2017/02/china-artificial-intelligence/516615/.

Zhong, Raymond, and Sui-lee Wee. "China Seeks Small Stakes in, and More Sway Over, Online Firms." The New York Times. October 13, 2017. Accessed December 07, 2017. https://www.nytimes.com/2017/10/13/business/china-online-stakes-control.html.

Zweig, D. and Wang, H., 2013. Can China bring back the best? The Communist Party organizes China's search for talent. The China Quarterly, 215, pp.590-615.