

Paul Scharre: Four Battlegrounds for Artificial Intelligence

The article below is based on the text from Paul Scharre's talk at the NBER AI Conference on September 19, 2024 in Toronto which in turn builds on his book "Four Battlegrounds".

I want to start by just grounding the discussion in where we are today with artificial intelligence and robotics in warfare.

I was in Ukraine earlier this year and had the opportunity to meet with drone developers, drone pilots, and leadership from the Ukrainian government and armed forces.

Drones are heavily used in the Ukraine war by both sides, but most of these drones are remotely piloted.¹

This of course makes them completely dependent on the communications link to their human operators. Without that communications link, the drone is useless. So both sides have turned to electronic warfare to jam the communications link. There is an enormous amount of jamming on both sides, leading to very high loss rates among drones.² And both sides are desperate to find ways to make the drones more effective in this highly contested electromagnetic environment.

Autonomy is one possible solution. Ukrainian armed forces are working on what they call the "autonomous last mile solution," autonomous terminal guidance to guide the drone into its target once the human operator has chosen the target.³

I got a chance to see this in action.

We went to the range, and I saw a Ukrainian drone developer demonstrate this autonomous last mile solution. They locked onto a target. The drone pilot took his hands off the controls. And the automation did the rest. The automation took over and the drone zoomed right into the target all on its own and hit it.

What I saw demonstrated was very simple technology. It didn't use any sophisticated machine learning. It essentially locked onto some pixels and kept the drone centered on them as it flew towards the target.

¹ Stacie L. Pettyjohn, "Drones are Transforming the Battlefield in Ukraine But in an Evolutionary Fashion," War on the Rocks, March 5, 2024, <https://warontherocks.com/2024/03/drones-are-transforming-the-battlefield-in-ukraine-but-in-an-evolutionary-fashion/>.

² "Many Ukrainian drones have been disabled by Russian jamming," *The Economist*, May 29, 2024, <https://www.economist.com/science-and-technology/2024/05/29/many-ukrainian-drones-have-been-disabled-by-russian-jamming>.

³ Max Hunder, "Ukraine rushes to create AI-enabled war drones," Reuters, July 18, 2024, <https://www.reuters.com/technology/artificial-intelligence/ukraine-rushes-create-ai-enabled-war-drones-2024-07-18/>.

This wasn't done by an advanced defense company. It was essentially a guy in his garage. That's how widely available this technology is.

The longer that the war in Ukraine drags on, the more likely we are to see innovation on both sides. War is an accelerant of military innovation.

We could be months away from autonomous weapons being used in Ukraine, where the drones, using AI, are carrying out attacks entirely on their own without any human intervention once they're launched.

It is possible that it is happened already and we just don't know it yet.

In fact, one Ukrainian company has claimed that they have already built and deployed a fully autonomous weapon that has been used in combat,⁴ although this claim has not been independently verified.

Things are moving fast.

And you can see that in fact what's happening on the battlefield is still several years behind the state-of-the-art in AI.

Machine learning image classifiers are over 10 years old now.⁵ This is old technology. This doesn't even account for what's happening today in AI.

What I wanted to talk with you about today is where we are headed.

Things are moving incredibly fast in the field of AI. We're seeing profound changes underway.

And I don't know that anyone can say for certain what kind of progress we'll see in the next 12 months, much less the next decade.

Like so many of us, I imagine you are thinking deeply about the changes we're seeing in our world and you're trying to figure out how to best anticipate the challenges ahead.

⁴ David Hambling, "Ukrainian AI attack drones may be killing without human oversight," NewScientist, October 13, 2023, <https://www.newscientist.com/article/2397389-ukrainian-ai-attack-drones-may-be-killing-without-human-oversight/>; David Hambling, "Ukraine's AI Drones Seek And Attack Russian Forces Without Human Oversight," Forbes, October 17, 2023, <https://www.forbes.com/sites/davidhambling/2023/10/17/ukraines-ai-drones-seek-and-attack-russian-forces-without-human-oversight/>.

⁵ "AlexNet and ImageNet: The Birth of Deep Learning," Pinecone, n.d., <https://www.pinecone.io/learn/series/image-search/imagenet/>.

With that in mind, I want to zoom out and talk about some bigger picture shifts in how artificial intelligence is changing global power.

2. China

China's leader Xi Jinping has said, "Science and technology has become the main battleground of global power rivalry."⁶

Are democratic nations ready for that competition?

200 years ago, we saw during the industrial revolution that nations rose and fell on the global stage based on how rapidly they industrialized.⁷

At the start of the industrial revolution, Russia led Europe in economic power by virtue of its vast size.⁸

Yet Great Britain and Germany industrialized faster, while Russia fell behind.

By the turn of the 20th Century, Great Britain and Germany had eclipsed Russia in economic power.

Artificial intelligence has a similar potential to change the global balance of power today.

We want to believe that we're Great Britain or Germany.

But deep down our fear is that we might be Russia.

And China might be on track to lead the world in AI.

3. Open society

I'm going to tell you a story that, on the surface, sounds like we're Russia.

⁶ Coco Feng, "Chinese President Xi Jinping seeks to rally country's scientists for 'unprecedented' contest," *South China Morning Post*, May 29, 2021, <https://www.scmp.com/news/china/politics/article/3135328/chinese-president-xi-jinping-seeks-rally-countrys-scientists>; "（受权发布）习近平：在中国科学院第二十次院士大会、中国工程院第十五次院士大会、中国科协第十次全国代表大会上的讲话 [(Authorized Release) Xi Jinping: Speech at the 20th Academician Conference of the Chinese Academy of Sciences, the 15th Academician Conference of the Chinese Academy of Engineering, and the 10th National Congress of the Chinese Association for Science and Technology]," Xinhua, May 28, 2021, http://www.xinhuanet.com/politics/2021-05/28/c_1127505377.htm.

⁷ Paul Kennedy, *The Rise and Fall of the Great Powers* (New York: Random House, 1987), 197.

⁸ Kennedy, *The Rise and Fall of the Great Powers*, 171.

But as you'll see, is not as bad as it looks.

It's about facial recognition and about how China is ahead of the United States and Europe in facial recognition deployment.

China has half of the world's one billion surveillance cameras.⁹

And they increasingly use AI tools like facial recognition and gait recognition to identify and track individuals.¹⁰

The Chinese Communist Party is building a massive domestic surveillance system.

These investments not only fund Chinese AI companies, but even more importantly they give Chinese companies data to train their algorithms.

And by using their facial recognition systems in the real world, Chinese companies get to improve their algorithms.

Meanwhile, in the United States it **seems** like we're totally behind.

Facial recognition deployment has stalled out in the United States.

There has been a grass roots movement of cities and states banning facial recognition by law enforcement.¹¹

⁹ Liza Lin and Newley Purnell, "A World with a Billion Cameras Watching You Is Just Around the Corner," *Wall Street Journal*, December 6, 2019, <https://www.wsj.com/articles/a-billion-surveillance-cameras-forecast-to-be-watching-within-two-years-11575565402>.

¹⁰ *Risks and Considerations for Businesses with Supply Chain Exposure to Entities Engaged in Forced Labor and Other Human Rights Abuses in Xinjiang* (Department of State, July 1, 2020), https://www.state.gov/wp-content/uploads/2020/07/Xinjiang-Supply-Chain-Business-Advisory_FINAL_For-508-508.pdf.

¹¹ Brian Fung, "Tech Companies Push for Nationwide Facial Recognition Law. Now Comes the Hard Part," *Philadelphia Tribune*, June 15, 2020, https://www.phillytrib.com/news/business/tech-companies-push-for-nationwide-facial-recognition-law-now-comes-the-hard-part/article_fe78e04e-e8be-5aab-9402-00203a44510f.html.

IBM,¹² Amazon,¹³ and Microsoft¹⁴ have all said they won't sell their facial recognition software to law enforcement.

On the surface, it seems like maybe we're Russia, and China is racing ahead while we're left behind.

On the surface, it seems like China is poised to win the AI revolution.

But what we may not realize is that the winner of the AI revolution won't be who has the best technology, but who finds the best ways of using it.

That means using it in every aspect of society – for economic productivity, for social welfare, and for military applications.

Yes, Chinese companies will have more data on Chinese faces, but that won't help them train AI fighter pilots.

What *is* going to train AI fighter pilots is not facial recognition, it is actually military and civilian scientists working together to find the best ways of using AI for military advantage.

We worry that having an open society can slow us down.

China's deployed half a billion cameras while we're still debating the issue.¹⁵

The Chinese Communist Party can simply dictate how Chinese society will adopt a new technology.

Meanwhile, in America, there's a messy give-and-take among state, local, and federal authorities, the private sector, civil society, and ordinary citizens.¹⁶

But that is actually a strength. Because what matters most is finding the best ways of using technology.

¹² Hannah Denham, "IBM's Decision to Abandon Facial Recognition Technology Fueled by Years of Debate," *Washington Post*, June 11, 2020, <https://www.washingtonpost.com/technology/2020/06/11/ibm-facial-recognition/>.

¹³ "We Are Implementing a One-Year Moratorium on Police Use of Rekognition," Amazon, June 10, 2020, <https://blog.aboutamazon.com/policy/we-are-implementing-a-one-year-moratorium-on-police-use-of-rekognition>.

¹⁴ Jay Greene, "Microsoft Won't Sell Police Its Facial-Recognition Technology, Following Similar Moves by Amazon and IBM," *Washington Post*, June 11, 2020, <https://www.washingtonpost.com/technology/2020/06/11/microsoft-facial-recognition/>.

¹⁵ Liza Lin and Newley Purnell, "A World with a Billion Cameras Watching You Is Just Around the Corner."

¹⁶ Brian Fung, "Tech Companies Push for Nationwide Facial Recognition Law. Now Comes the Hard Part."

The United States and Europe have fundamental strengths in the AI competition that China cannot match – our open societies are a magnet for global talent, and our network of alliances dominate the AI hardware ecosystem.

But we have to harness those strengths.

My book, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, outlines what it will take for the United States to win the AI revolution and remain a global leader in artificial intelligence.¹⁷

It will require being strategic.

We don't need to do everything.

We just need to do a few key things right to stay ahead.

What I do in the book and what I want to do with you today, is talk about what actually matters in this competition and outline how the United States and Europe can win.

4. Four battlegrounds

But if we really want to understand how to dominate in AI power, we *first* need to understand how artificial intelligence is changing global power.

So let's go back to the industrial revolution.

The industrial revolution saw the key metrics of power change.

Coal and steel became key inputs of national power.¹⁸ Oil became a geostrategic resource that nations were willing to fight wars over.

So what is “the new oil” today?

I want to argue that data, computing hardware, human talent, and institutions are the four key battlegrounds of geopolitical competition in artificial intelligence.

The first two, data and computing hardware, are technical inputs into AI.

¹⁷ Paul Scharre, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, (New York: W.W. Norton and Co).

¹⁸ Kennedy, *The Rise and Fall of the Great Powers*, 199–202, 258, 271; John J. Mearsheimer, *The Tragedy of Great Power Politics*, (New York: W.W. Norton and Co, 2014, 64–66.

The AI revolution is being driven by dramatic progress in machine learning, in which algorithms are trained on data.

Data, algorithms, and computing hardware are the three technical resources needed for machine learning.

It's difficult to control the spread of algorithms. The AI research community is incredibly open, with new breakthroughs published online.

So any competitive advantage is likely to come from data or computing hardware.

The second two battlegrounds of AI competition are the social software that enables AI, human talent and institutions -- the organizations that shape AI adoption.

Whichever companies – and countries – lead in these four areas will lead an AI-driven future.

5. Data

Let's talk about data.

Data is an essential resource for machine learning.

Cutting-edge machine learning models use massive amounts of data.

Image recognition models use millions of labeled images.¹⁹

Large language models like ChatGPT are trained on trillions of words.²⁰

So, does China have a data advantage?

In theory, China's alleged authoritarian advantage in data comes from its larger population and massive government surveillance.²¹

Both of these things are true, but they don't necessarily add up to a data advantage.

¹⁹ Alex Krizhevsky, Ilya Sutskever, Geoffrey E. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," in Advances in Neural Information Processing Systems 25, https://proceedings.neurips.cc/paper_files/paper/2012/file/c399862d3b9d6b76c8436e924a68c45b-Paper.pdf.

²⁰ Pablo Villalobos et al. "Will We Run Out of Data? Limits of LLM Scaling Based on Human-Generated Data." Epoch, June 6, 2024. <https://epochai.org/blog/will-we-run-out-of-data-limits-of-llm-scaling-based-on-human-generated-data>

²¹ Shoshana Zuboff, *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power* (New York: PublicAffairs, 2019).

For one, a country's population matters far less than the user base of tech companies.

U.S. tech companies have global reach. Facebook and YouTube have over 2 billion users each.²²

WeChat, meanwhile, has only 1.2 billion users.²³ In fact, except for TikTok, Chinese social media platforms have struggled to succeed outside of China.

And while the Chinese Communist Party has built a massive surveillance system for monitoring its citizens, that does not always translate into greater access to data for Chinese companies.

In some areas, like facial recognition, Chinese companies are likely to have an edge over competitors, but that doesn't necessarily translate into an advantage in AI overall.

In other areas, like large language models, the Chinese government is regulating AI companies much more heavily than the U.S. government.²⁴ The Chinese Communist Party heavily censors the internet in China and wants to clamp down on what large language models might say online.

And while there are no restrictions in China on government spying, that isn't the case for companies. In fact, the Chinese government has been cracking down on what private companies can do.²⁵ The Chinese Communist Party doesn't want anyone else to have the same spying powers that it has.

²² Facebook, "Facebook Reports Third Quarter 2020 Results," news release, October 29, 2020, <https://investor.fb.com/investor-news/press-release-details/2020/Facebook-Reports-Third-Quarter-2020-Results/default.aspx>; "YouTube for Press," YouTube Official Blog, n.d., <https://blog.youtube/press/>.

²³ Tencent, "Tencent Announces 2020 Third Quarter Results," news release, Hong Kong, November 12, 2020, <https://static.www.tencent.com/uploads/2020/11/12/4c2090d5f6f00fd90ddc9bbd9a1415d1.pdf>.

²⁴ Anjali C. Das, "China's New Personal Information Protection Law," *National Law Review*, December 2, 2021, <https://www.natlawreview.com/article/china-s-new-personal-information-protection-law>; Rogier Creemers and Graham Webster, "Translation: Personal Information Protection Law of the People's Republic of China—Effective Nov. 1, 2021," *DigiChina*, August 20, 2021, <https://digichina.stanford.edu/work/translation-personal-information-protection-law-of-the-peoples-republic-of-china-effective-nov-1-2021/>; Liisa M. Thomas, Julia K. Kadish, and Kari M. Rollins, "Update on the State of Privacy Law in China," *National Law Review*, September 20, 2021, <https://www.natlawreview.com/article/update-state-privacy-law-china>; Eva Dou, "China Built the World's Largest Facial Recognition System. Now, It's Getting Camera-Shy," *Washington Post*, July 30, 2021, https://www.washingtonpost.com/world/facial-recognition-china-tech-data/2021/07/30/404c2e96-f049-11eb-81b2-9b7061a582d8_story.html; Laura He, "China Is Raising the Alarm Over Corporate Surveillance. But It's Got a Massive Network of Its Own," *CNN Business*, March 19, 2021, <https://edition.cnn.com/2021/03/19/tech/china-consumer-rights-surveillance-intl-hnk/index.html>.

²⁵ Anjali C. Das, "China's New Personal Information Protection Law," Rogier Creemers and Graham Webster, "Translation: Personal Information Protection Law of the People's Republic of China—Effective Nov. 1, 2021," Liisa M. Thomas, Julia K. Kadish, and Kari M. Rollins, "Update on the State of Privacy Law in China," Eva Dou, "China Built the World's Largest Facial Recognition System. Now, It's Getting Camera-Shy," Laura He, "China Is Raising the Alarm Over Corporate Surveillance. But It's Got a Massive Network of Its Own."

Both the U.S. and China have access to ample amounts of data. What will matter more is how they use it.

The real data advantage will be those who are successful in building a pipeline for collecting and refining data so that it's ready to be used for machine learning.

The self-driving car company Waymo is an instructive example. They have over 10 million driverless miles.²⁶ But they've also done 20 billion miles in simulations to rack up the data they need to train their models.²⁷ For robotic systems, using synthetic data to augment real-world data can help train more robust systems.

Organizations that will have a data advantage are those that can successfully harness data for machine learning.

6. Hardware

Machine learning models are trained on data using hardware.

So let's talk about the hardware dimension of this competition – the second battleground of AI competition

If data is overrated, hardware is often underrated as an element of strategic competition.

From the 1950s on, improvements in computing hardware have been governed by Moore's law, a doubling in computing performance about every 24 months.²⁸

Now you may have heard that Moore's law is dead, but in fact what's happening now is way more interesting. Since 2010, we've seen an explosion in computing hardware for machine learning.²⁹

The amount of computing hardware used to train the most advanced AI models is doubling every 6 months,³⁰ must faster than the 24-month doubling rate under Moore's law.

²⁶ Brian Wilt (@brianwilt) "When I posted this last February, I wasn't expecting that it would take less than a year to pass 10M driverless miles." X (formerly Twitter), January 30, 2024. <https://x.com/brianwilt/status/1752457616897478881>

²⁷ "Waymo Raises First External Investment Round," Waymo blog, March 2, 2020, <https://blog.waymo.com/2020/03/waymo-raises-first-external-investment.html>.

²⁸ Gordon E. Moore, "Cramming More Components onto Integrated Circuits," *Proceedings of the IEEE* 86, no. 1 (January 1998): 82-85, <https://www.cs.utexas.edu/~fussell/courses/cs352h/papers/moore.pdf>

²⁹ Besiroglu, Tamay, et al. "Projecting Compute Trends in Machine Learning." Epoch, March 7, 2022. <https://epochai.org/blog/projecting-compute-trends>.

³⁰ Jaime Sevilla and Edu Roldán, "Training Compute of Frontier AI Models Grows by 4-5x per Year." Epoch, May 28, 2024. <https://epochai.org/blog/training-compute-of-frontier-ai-models-grows-by-4-5x-per-year>.

And that's a product of two things. First of all, chips continue getting better. The price-performance, or performance per dollar, for machine learning GPUs is still doubling every 24 months.³¹ Plus, tech companies are pouring massive amounts of money into these chips. They're buying more chips and networking them together for massive training runs using tens of thousands of chips. Independent estimates put the cost of the final training run for GPT-4 at around \$50 million or so,³² and the cost for training the most advanced models is doubling around every 10 months.³³ That's on top of the fact that the chips themselves are doubling in performance per dollar every 24 months. So you have an exponential on top of an exponential, and you get massive growth in computing hardware.

On top of those trends in chips and spending, you actually get a third exponential, which is algorithmic improvements. Algorithms are improving in their hardware efficiency. That is, algorithms are getting better, allowing you to squeeze more capability out of the same amount of computing power. That's a bit trickier to measure, but research suggests that algorithmic efficiency is doubling about every eight to nine months for large language models.³⁴ So every 8 or 9 months, you can get twice as much capability with the same amount of computing power.

These three stacked exponentials in chip performance, spending, and algorithmic improvements are what's driving an unbelievable growth rate in computing power for the most advanced AI systems. If current trends continue, by 2030 we will see AI models trained on one million times more effective computing power than the current state of the art.³⁵

I don't know what such systems will be capable of doing – no one does. But this increased computing power will open up new opportunities.

We are heading into an era of compute-intensive machine learning, where the largest and most capable models use massive amounts of compute.

This means computing hardware is increasingly a strategic resource that will determine who has access to the most advanced AI capabilities.

We're used to thinking of semiconductors as a foundational technology that empowers all of the digital devices we have, from our phones to factories.

³¹ Florian E. Dorner, *Measuring Progress in Deep Reinforcement Learning Sample Efficiency*. arXiv.org, February 9, 2021. <https://arxiv.org/abs/2102.04881>.

³² https://colab.research.google.com/drive/1O99z9b1I5O66bT78r9ScsIE_nOj5irN9#scrollTo=CytB-eruRSGB

³³ Ben Cottier, "Trends in the Dollar Training Cost of Machine Learning Systems." Epoch, January 31, 2023. <https://epochai.org/blog/trends-in-the-dollar-trainingcost-of-machine-learning-systems>.

³⁴ Paul Scharre, *Future-Proofing Frontier AI Regulation: Projecting Future Compute for Frontier AI Models* (Center for a New American Security, March 2024), https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/CNAS-Report_AI-Trends_FinalC.pdf

³⁵ Paul Scharre, *Future-Proofing Frontier AI Regulation: Projecting Future Compute for Frontier AI Models*.

But the trends in compute-intensive machine learning suggest something different.

Semiconductors are poised to be a strategic global asset, like access to enriched uranium.

That divides the world into haves and have nots.

What makes computing hardware so valuable is that it is a physical thing that we can restrict others from using.

And in fact the United States and its allies are already doing so.

Five countries control access to the most advanced chips:

Taiwan and South Korea, where the most advanced chips are made.³⁶

And the Netherlands, Japan, and the United States, who make the equipment used to manufacture the most advanced chips.³⁷

The Netherlands and Japan have joined U.S. export controls on advanced AI chip-making equipment to China.³⁸ And the U.S. government has banned the shipment of advanced chips to China.³⁹

In the near-term, China has no alternative way of getting these chips.

Without access to the equipment needed to manufacture chips, China will have a steep hill to climb to build a fully indigenous supply chain.

Our alliances are a core strength that China cannot compete with if we work together.

7. Talent

³⁶ Rob Toews, "The Geopolitics of AI Chips will Define the Future of AI," *Forbes*, May 7, 2023, <https://www.forbes.com/sites/robtoews/2023/05/07/the-geopolitics-of-ai-chips-will-define-the-future-of-ai/>.

³⁷ Saif M. Khan and Carrick Flynn, *Maintaining China's Dependence on Democracies for Advanced Computer Chips* (Brookings Institution, April 2020), https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_computer_chips_khan_flynn.pdf.

³⁸ Gregory C. Allen, Emily Benson, and Margot Putnam, *Japan and the Netherlands Announce Plans for New Export Controls on Semiconductor Equipment* (Center for Strategic & International Studies: April 10, 2023), <https://www.csis.org/analysis/japan-and-netherlands-announce-plans-new-export-controls-semiconductor-equipment>.

³⁹ Sujai Shivakumar, Charles Wessner, and Thomas Howell, *Balancing the Ledger: Export Controls on U.S. Chip Technology to China* (Center for Strategic & International Studies: February 21, 2024), <https://www.csis.org/analysis/balancing-ledger-export-controls-us-chip-technology-china>.

People are needed to turn the raw inputs of data and computing hardware into useful AI tools.

So let's talk about the third battleground, talent.

There is a fierce competition for global talent.

Freshly minted graduates from AI PhD programs are commanding professional sports level salaries from top AI labs.⁴⁰

Globally, there is a fierce competition among countries as well.

China produces more of the top AI scientists in the world than any other country.⁴¹

But here's the thing -- those top Chinese scientists don't stay in China.

China's top undergraduates leave China and come to the United States and Europe for graduate school.⁴²

And they stay outside China.⁴³

90 percent of Chinese undergraduates who do their PhD in AI in the United States stay in the U.S. after graduation.

The United States and Europe have a massive advantage in human talent that China cannot match.

Yes, there are problems of intellectual property theft and academic espionage.

⁴⁰ Cade Metz, "Tech Giants Are Paying Huge Salaries for Scarce A.I. Talent," *New York Times*, October 22, 2017, <https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html>; Jeremy Kahn, "Sky-High Salaries Are the Weapons in the AI Talent War," *Bloomberg Businessweek*, February 13, 2018, <https://www.bloomberg.com/news/articles/2018-02-13/in-the-war-for-ai-talent-sky-high-salaries-are-the-weapons>.

⁴¹ "The Global AI Talent Tracker," Macro Polo, n.d., <https://macropolo.org/digital-projects/the-global-ai-talent-tracker/>.

⁴² Paul Mozur and Cade Metz, "A U.S. Secret Weapon in A.I.: Chinese Talent," *New York Times*, June 9, 2020, updated April 13, 2021, <https://www.nytimes.com/2020/06/09/technology/china-ai-research-education.html>.

⁴³ Remco Zwetsloot, *Keeping Top AI Talent in the United States* (Center for Security and Emerging Technology, December 2019), 10, <https://cset.georgetown.edu/wp-content/uploads/Keeping-Top-AI-Talent-in-the-United-States.pdf>.

China has an estimated over 200 talent recruitment plans to bring overseas scientific knowledge back to China.⁴⁴

And we need to police that and improve research security to de-risk these talent flows, to put guardrails in place so that we can continue these research relationships.

Because the United States and Europe benefit disproportionately from these connections to Chinese researchers.

Even while we're competing with China, pursuing a strategy of pure decoupling from China in AI is not the answer.

The United States, Europe, and other democratic allies also need to find better ways to harness the talent we have – to make it easier for our scientists to collaborate with one another.

Creating something like a Schengen visa for AI scientists among democratic nations, to make it easier for scientists to travel abroad and do visiting fellowships, could be a smart way to harness our collective strengths.

Our open societies and our alliances are core strengths in the global competition for AI talent.

8. Institutions

So you've got the data, the computing hardware, the talent – if you want to turn these raw inputs into useful AI applications, you need institutions that can do this. And that's the fourth battleground. The human organizations that are going to develop AI innovations.

I want to close with a story that shows how all of this can come together and bring things back to where we started: AI-enabled drone warfare.

Back in 2019, DARPA – the Pentagon's "Department of Mad Scientists" – started the Air Combat Evolution, or ACE, program to train an AI fighter pilot.⁴⁵

One of their first efforts was an AlphaDogfight challenge, taking a page from AlphaGo.

Various companies submitted their AI agents to compete in a simulated aerial combat, and the winning competitor got to go head-to-head against a human pilot.

⁴⁴ *Threats to the U.S. Research Enterprise: China's Talent Recruitment Plans* (staff report, Permanent Subcommittee on Investigations, Committee on Homeland Security and Governmental Affairs, US Senate, n.d.), <https://www.hsgac.senate.gov/wp-content/uploads/imo/media/doc/2019-11-18%20PSI%20Staff%20Report%20-%20China's%20Talent%20Recruitment%20Plans%20Updated2.pdf>.

⁴⁵ "Training AI to Win a Dogfight," Defense Advanced Research Projects Agency, May 8, 2019, <https://www.darpa.mil/news-events/2019-05-08>.

Heron Systems – a company no one had ever heard of – beat defense giant Lockheed Martin in the finals.⁴⁶

Then they went against an experienced Air Force fighter pilot.

And the AI absolutely crushed the human, fifteen to zero. The human pilot couldn't get a single shot off.⁴⁷

Even more amazing, the AI pilot won using a tactic that is essentially impossible for humans, taking head-to-head gunshots when the aircraft are racing at each other at hundreds of miles an hour and there is a split-second to get a shot off.⁴⁸ This is basically impossible for humans to make a shot like this – in fact, it's banned in training because it's dangerous for humans to even try this when the aircraft are racing towards each other, because they might risk a collision. But this wasn't a problem for the AI. Even more wild, the AI learned this tactic entirely on its own. It wasn't programmed in.

How did Heron Systems do this?

They build a competitive league of 100 AI agents flying against each other in simulations. So they built the data they needed. The winning agent had over 30 years of flight time in simulators.⁴⁹ That gave them the data.

They built the computing infrastructure they needed to run these simulations non-stop. In fact, when I visited their offices, I could hear the roar of the computer servers churning away simulations in their server closet.

They harnessed their talent. One of their company policies was "Fun Fridays" in which programmers could work on their own pet projects one day a week. One of their programmers was excited by reinforcement learning, a technique that was showing breakthroughs in AI research, and built a "Doom bot" to play the computer game Doom.⁵⁰

⁴⁶ Scharre, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, 1.

⁴⁷ Scharre, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, 1.

⁴⁸ Colin "Farva" Price, "Navy F/A-18 Squadron Commander's Take on AI Repeatedly Beating Real Pilot In Dogfight," *The Drive*, August 24, 2020, <https://www.thedrive.com/the-war-zone/35947/navy-f-a-18-squadron-commanders-take-on-ai-repeatedly-beating-real-pilot-in-dogfight>.

⁴⁹ Scharre, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, 221.

⁵⁰ Scharre, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, 221.

And when they went to pitch DARPA on being allowed to compete in AlphaDogfight, it was actually the Doom bot playing in the background that piqued the DARPA program manager's interest.⁵¹ Because here was an example of them actually doing reinforcement learning.

And none of this would have been possible without an organization like DARPA sponsoring the AlphaDogfight challenge, being willing to take on a hard problem, and creating the space for new startups to compete and win.

After winning, Heron Systems got bought by ShieldAI, one of a slew of new defense-oriented AI startups.⁵²

And in late 2022, DARPA conducted real-world flights with AI agents on an F-16 fighter jet, moving from simulator to the real world.⁵³

This isn't just the story about one company.

The AI fighter pilot story tells us what success looks like and how the United States and its allies will be able to lead in AI.

By harnessing data, computing hardware, and talent and creating the institutions needed to find the best ways of using AI to preserve national advantage.

The United States, Europe, and other democratic countries have tremendous strengths in this competition. If we harness them, democratic nations can lead an AI-driven future.

⁵¹ Scharre, *Four Battlegrounds: Power in the Age of Artificial Intelligence*, 221.

⁵² Jackson Barnett, "Shield AI buys company whose AI beat a fighter pilot in a dogfight," FedScoop, July 22, 2021, <https://fedscoop.com/shield-ai-buys-company-whose-ai-beat-a-fighter-pilot-in-dogfight/>.

⁵³ Michael Marrow, "In a 'world first,' DARPA project demonstrates AI dogfighting in real jet," Breaking Defense, April 19, 2024, <https://breakingdefense.com/2024/04/in-a-world-first-darpa-project-demonstrates-ai-dogfighting-in-real-jet/>.