Comment on Scharre: Four Battlegrounds

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There is a growing view that we are racing into a future where wars are fought and won with autonomous, AI-driven weapons across all domains—land, sea, air, space, and cyber.

Proponents of this view point to recent and active conflicts, and to military innovation pipelines (e.g., Scharre 2018, Brose 2020). Autonomy has been a prominent theme in military technology for decades—with a history tracing through automatic machine guns, automatic gun-laying radar, heat-seeking missiles, unmanned aerial vehicles, and more. The meaning of autonomy has itself expanded over time, from mechanization (a mechanical layer between human operators and machine operation), to electronic control (a software layer), to cybernetics (self-regulation through feedback loops; e.g., autopilot). All three are now prevalent in military hardware, including vehicles and weapons.

In all of these cases, however, a human sits at the top of the kill chain, using judgment and discretion to identify targets and make the choice to engage them. Artificial intelligence (AI) now has the potential to automate this too, opening up new possibilities and fears about the future of war—or even civilization—when control is delegated to algorithms, and humans are taken out of the loop.

Are we on the precipice of a new era of warfare: the age of AI? If so, what will determine the military advantage of nations in the era of drone swarms and clone wars?

Artificial intelligence at war

According Scharre (2023)'s Four Battlegrounds: Power in the Age of Artificial Intelligence, this future has arrived—and the critical question is who is poised to win.

Getting a handle on this question requires first a better understanding of what functions AI can serve in combat settings. These cases might be usefully reduced to two categories:

1. *Automating routine tasks.* Complement high-skill humans, who remain in the loop but can focus their time and attention on non-routine cases requiring judgment. Example: target identification.

2. *Undertaking complex tasks.* Substitute for humans—with the goal of opening new frontiers for military strategy. Example: coordinated operation of massive numbers of attritable units.

The central thesis of Scharre (2023) is that military advantage this century will hinge on four critical AI assets: data, compute, talent, and institutions. One might think of this as a framework—a "resource-based view" of military performance—paralleling the resource-based view (RBV) of firm strategy (Wernerfelt 1984), which argues that firms' internal resources and capabilities are their primary source of competitive advantage. Control over AI resources, according to Scharre, constitutes the "four battlegrounds" where the future will be won or lost. Though one might contend it is not enough to simply control resources: Porter (1996) and others have argued that effective strategies must also integrate these resources, making them work together such that the whole is more than the sum of the parts.

Scharre (2023) uses much of his book to discuss opportunities, challenges, and especially geopolitical competition for each of these resources, focused on the U.S. and China. At the present moment, it is hard to think about military AI without this competition being a central focus. By and large, most observers—including some participants of this conference—argue that China is outcompeting (some might even say

[1] I am grateful for helpful comments from participants in the Fall 2024 NBER Economics of Artificial Intelligence conference and co-editor Avi Goldfarb for helpful comments. All errors are my own.

dominating) the U.S. and NATO allies in these battlegrounds. Arguments often point to the size of China's population, the power of the state, the level of AI technology development, and the size of the industrial base as sources of advantage across the four battlegrounds. Yet it is not clear that all of these resources are general-purpose enough to confer broad or insurmountable advantages (e.g., data are typically domain-specific, frontier AI requires frontier chips and chip-making equipment, etc.). Where there are gaps, history suggests these can also potentially be closed quickly: at the dawn of World War II, Germany led the military technology frontier, but by the end of the war, the U.S. did. This reversal of fortunes was made possible, however, by existing investments that created a platform of science, talent, and industrial capacity that could be mobilized for war and rapidly progressed.

<u>How close are we to the clone wars?</u>

Is it time to panic?

At the time of writing, ongoing hot wars around the world suggest we are still awaiting the AI revolution in combat. The war in Ukraine is more or less a conventional war, fought with major weapons systems, heavy artillery, and human attrition. The war in Gaza is more or less a guerilla war being fought in dense urban warzones. Each mode of war has historical precedents—such as World War II or Vietnam. Where AI is being used in combat, it appears to be in more tactical applications. Scharre (2023), for example, describes Ukrainian development of autonomous "last mile" solutions for drone attacks, where remote pilots may lose contact or visibility and delegate operation to the machine.

Changing how wars are fought, however, is a systems problem—and systems problems are hard (Agarwal et al. 2022). In the past 15 years, more than one U.S. military service effort to develop modern "systems of systems" for combat have collapsed under the weight of their own complexity—like the Army's Future Combat Systems (FCS) program or Coast Guard's Deepwater program.

One source of inertia is organizational dynamics. A sizable literature in economics, management, and associated fields has documented the challenges large organizations face in incorporating and adapting to new technology (e.g., Milgrom and Roberts 1990). DoD is the second-largest organization in the world by headcount (behind the Indian Ministry of Defense, and ahead of the Chinese People's Liberation Army), and undertakes a wide ranger of activities than even the largest private firms. Human-centric military strategy and organizational routines have been refined over centuries, with significant interdependencies in and across combat and non-combat operations. Competing interests, information silos, bureaucracy, and existing technology also tend to slow change. As the world's dominant superpower for the past three to four decades, the U.S. military in particular has been less incentivized to upend itself (Arrow 1962)—though this is now changing with geopolitical competition from China.

The R&D problem is also complex. AI-driven systems are fundamentally software-driven systems, and these have been growing in complexity for decades: compared to the Apollo Guidance Computer that took humans to the moon, a modern F-35 Joint Strike Fighter has over 50x as many lines of code (~8 million vs. <150,000; McCandless 2015), with its concomitant interdependencies too. Beyond software, coordinated, AI-powered weapons systems will likely also require networks of tens of thousands of sensors providing real-time data feeds, and powerful computers supporting autonomous decisions in microseconds while withstanding the rigors of a battlefield. Each of Scharre (2023)'s four battlegrounds represents an essential ingredient. But these pieces also need to come together in a coordinated system, which it appears will require a fundamentally different military-technological architecture (in the spirit of Henderson and Clark 1990). Here, too, AI introduces new weaknesses for military use: security vulnerabilities, power requirements, and potential countermeasures may limit its value, at least in the short-run, as a basis for systemic change in the nature and conduct of war.

Though one cannot fully rule out that some undisclosed new capabilities are already in place—frontier military technology is often classified (Gross 2023)—experience and economic logic suggests there are reasons to believe changes in how wars are fought will take some time.

AI transformation behind the scenes?

However, weapons of war are only one of many use cases for AI in large militaries. The applications that create the most value may be elsewhere—and might be implemented well before large drone swarms. Recruiting, screening, and training tens of thousands of warriors; predictive maintenance on billions of dollars of equipment; and the review of millions of hours of surveillance video or digital communications are all activities that consume significant resources on an ongoing basis where AI might provide large productivity gains. Even in war, history has shown that non-combat problems like military supply logistics may benefit from AI: a 1980s AI decision-support tool for optimizing the routing of supplies and personnel, originally funded by DARPA as an experimental system, was deployed in the Gulf War and achieved a level of savings that was claimed to be the monetary equivalent of all funding DARPA had directed to AI research *for the prior 30 years combined* (Hedberg 2002).

Critical questions at the intersection of the economics of AI and national security

Important questions nevertheless remain in Scharre (2023)'s four battlegrounds. These are profoundly important opportunities for further work. I offer a few examples. *On data:* Are the marginal returns to data in AI innovation increasing or decreasing? When do data have dual-use value? How important are human-specified models as a complement to (or substitute for) machine learning in problems where data are intrinsically scarce, such as certain mobilization and combat functions? *On compute:* How well are policies to advance frontier chip R&D, on-shore supply chain, and limit foreign access working? To what degree does export control motivate catch-up R&D by adversaries? *On talent:* What are the effects of education and immigration policy—the weapons in this battleground—on AI talent acquisition and retention? What attracts top AI talent to the defense sector? *On institutions:* What policies foster a defense AI industrial base—and what keeps firms from participating? What are the organizational impediments to adopting AI in military settings, and the effects of specific AI systems on performance?

The biggest question, however, is not what but when: is an "AI revolution" in warfare imminent? It is useful to remember that AI research has been underway for 60+ years—and most of that time DoD was its leading patron. Autonomy broadly, and AI specifically, are not new to the military, but the present moment is increasingly seen as an inflection point vis-à-vis AI's technological potential.

Yet in the battlefield, as in business, we are still waiting for transformative change. The innovation problem is complex. The organizational one possibly even more. This kind of systemic change may wait until a crisis forces a scaled-up R&D effort and an accelerated organizational evolution that puts it into practice. Ruttan (2006) argues that "a major war, or the threat of major war, [is] necessary to mobilize the scientific, technical, and financial resources" needed to make progress. My own work (e.g., Gross and Sampat 2021, 2023; Gross and Roche 2024), which has studied past conflagrations, reinforces this view. The high cost of failure can motivate not only a deluge of public funding, but also a willingness to take more risk than usual, including parallel attempts that otherwise look wasteful. It can also inspire new approaches to innovation, including large, coordinated, cross-sectoral attacks on complex technological problems. Past examples, like radar or the atomic bomb in World War II, or even (more recently) Covid-19 vaccines, have engaged the full value chain, from research to mass production and deployment—overcoming coordination failures which in ordinary times make it hard for complex technologies to progress. Importantly, however, in these examples, the response drew from (and depended on) existing science, research talent, and domestic manufacturing capabilities.

Given this, it seems critical to stock the arsenal of Scharre's four battlegrounds now, so that they are ready to be put to work when the next great power conflict arises.

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