The Artificial Intelligence Arms Race: Trends and World Leaders in Autonomous Weapons Development

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Special Section Article

Abstract

Autonomous weapons technologies, which rely on artificial intelligence, are advancing rapidly and without sufficient public debate or accountability. Oversight of increased autonomy in warfare is critically important because this deadly technology is likely to proliferate rapidly, enhance terrorist tactics, empower authoritarian rulers, undermine democratic peace, and is vulnerable to bias, hacking, and malfunction. The top competitors in this arms race are the United States, China, Russia, South Korea, and the European Union.

Spending soars as progress stalls: where is the public debate on lethal artificial intelligence and autonomous weapons systems development?

As United Nations member states have made little progress in discussions of lethal autonomous weapons systems (AWS) over the last 5 years, the nature of warfare is transforming before our eyes. This change is occurring without proper accountability or public scrutiny as a handful of countries continue to make massive investments in increasing the autonomy of their weapons systems paired with advanced artificial intelligence (AI). Greater debate is urgently needed as lethal AWS are likely to proliferate rapidly, enhance terrorist tactics, empower authoritarian rulers, undermine democratic peace, and are vulnerable to bias, hacking, and malfunction. A proper public debate concerning the ramifications of 'killer robots' should start in earnest.

Technological advances in autonomy are often incremental and come with a low political profile. Autonomy is being added to different parts of existing weapons systems and meaningful human control, from target planning to mission execution, will be gradually lost without proper consideration of the moral dilemmas it raises (Roff, 2014; Sharkey, 2017; Schwarz, 2018). This widely unaccounted for development of AWS is taking place as the worldwide market is expanding rapidly. Global military spending on AWS and AI, narrowly defined, is projected to reach $16 and $18 billon respectively by 2025 (Sander and Meldon, 2014; Research and Markets, 2018).

This article proceeds as follows. The following section uses current events to project the future impacts that increasingly autonomous weapons, if left unchecked, could have on international security. The second section uses all publicly available data to establish and rank the top five world leaders according to their intent to develop autonomous technology, their capacity to develop AWS hardware, and their level of AI expertise. The final section highlights the importance of ongoing efforts to restrict or ban the use of AWS and of setting global norms under international law now by these leading states, before it is too late.

Projections from current trends in lethal AI and AWS development

Autonomous weapons are poised for rapid proliferation. At present, this technology is concentrated in a few powerful, wealthy countries that have the resources required to invest heavily in advanced robotics and AI research. However, Moore's Law and the declining costs of production, including 3D printing, will soon enable many states and non-state actors to procure killer robots (Scharre, 2014). At present, quadcopter drones cost as little as $25 and a small $35 Raspberry Pi computer can run AI advanced enough to defeat United States Air Force fighter pilots in combat simulations (Cuthbertson, 2016). Accountability will become increasingly difficult as more international actors are able to acquire lethal AWS. Houthi rebels are using weaponized drones and both ISIS and Boko Haram have adapted drones for use as

improvised explosive devices (Olaifa, 2018; Nissenbaum and Strobel, 2019). Proliferation to groups using terrorist tactics is particularly worrying because perceived costs drop as AWS increases the distance between the attacker and the target, making it less likely that they will be caught, while simultaneously increasing perceived benefits by allowing more precise target selection in order to maximize deadly impact and fear. Such offensive capabilities are likely to proliferate faster than lethal AI-based defensive systems due to protective technology having higher relative costs due to increased need to differentiate and safely engage targets.

Within states, lethal autonomy will likely empower authoritarian regimes and may intensify the global trend of democratic backsliding because AI-enhanced monitoring systems and robotic 'soldiers' are the perfect tools of despotic rule. While fully autonomous killer robots may not replace all traditional soldiers any time soon, focusing exclusively on such future trends risks missing the dystopian effects that AI is having in authoritarian states today. China has imprisoned millions of ethnic Uighurs and uses AI-based surveillance with facial recognition software to not only monitor Xinjiang province but to keep a close eye on all of its citizens (Human Rights Watch, 2019). Such surveillance systems have been deployed to over 70 Chinese cities and are being used to shape behavior via the 'social credit' system (Scharre, 2019). The authoritarian marketplace for such capabilities is strong, as China has held training sessions with officials from more than 30 countries seeking advanced tools for monitoring and controlling public opinion (Scharre, 2019).

Between states, full autonomy in war may undermine democratic peace (Altmann and Sauer, 2017). Immanuel Kant's theory of democratic peace relies upon the public not supporting unnecessary wars as they will be the ones called upon to fight in them. When many countries transitioned from a conscription or draft-based military to an all-volunteer force, public opposition to ongoing wars declined (Horowitz and Levendusky, 2011). This trend will likely be exacerbated and further lower the threshold for use of force when even fewer human soldiers are needed to fight wars (Cole, 2017; Garcia, 2014). Semi-autonomous systems have already begun to erode the fundamental norms of international law against the use of force (Bode and Huelss, 2018; Edmeades, 2017; Garcia, 2016).

Public oversight and accountability is particularly important because lethal AI-based systems are vulnerable to bias, hacking, and computer malfunction. As many as 85 per cent of all AI projects are expected to have errors due to either bias in the algorithm, biased programmers, or bias in the data used to train them (Gartner, 2018). AI bias tends to be particularly discriminatory against minority groups and could lead to over-targeting or false positives as facial recognition systems become further integrated into the weapons of war (West et al., 2019). Beyond bias, AI systems can be hacked, have unintended coding errors, or otherwise act in ways programmers never could have predicted. One such coding error happened in autonomous financial trading systems in May 2010 causing a 'flash crash' wiping out $1 trillion worth of stock market value in just a few minutes (Pisani, 2015). Even when correctly coded, many AI programs exploit unforeseen loopholes to achieve their programmed goals, such as a Tetris-playing AI that would pause the game just before the last block fell so that it could never lose, or another AI program that would delete the answer key against which it was being tested so that it could receive a falsely inflated perfect score (Scharre, 2019). The consequences of such bias and errors as AI is added to increasingly autonomous weapons could be devastating.

Top five world leaders in lethal autonomous weapons development

While most military spending figures are classified, our evaluation of the top leaders in AWS development makes use of what data is publicly available as a proxy to empirically gauge their relative standings. Table 1 displays the metrics we were able to use to rank each major actor and focuses on what we see as the three critical components for lethal AWS development. First, we examine the specific intent of countries to develop lethal AWS based on their official policies, actions, and public opinion. Second, we assess the general capacity and record of each actor with regard to developing cutting-edge lethal automated weapons hardware. Finally, we evaluate the most critical component, which is cultivating the artificial intelligence software expertise needed to enable AWS to carry out the complex tasks of war. The top five competitors in lethal AI and AWS development, are the United States, China, Russia, South Korea, and the European Union (EU)[1]

The United States

With a defense budget greater than the combined military spending of China, Russia, South Korea, and all 28 EU member-states combined, it is no surprise that the United States is the world leader in the development of lethal AWS (SIPRI, 2019). Autonomy has been an official component of United States national security strategy since 2012 with the release of Department of Defense (DoD) Directive 3000.09. This policy was the first of its kind and allows for semi-autonomous systems to engage targets pre-selected by human operators, as well as for fully autonomous weapons to select and engage targets after senior level DoD approval (Department of Defense, 2012). Further support for autonomy in war can be seen in the United States 'Third Offset Strategy' where it is listed as one of the main pillars. However, despite being a clear policy priority for defense officials, not all Americans support this effort. Only 25 per cent of American citizens trust AI, and some employees at major companies have resisted developing AI for military purposes, as seen in Google's internal rebellion against Project Maven, an AI development contract for the United States military (Ipsos, 2018).

The United States is the outright leader in autonomous hardware development and investment capacity. By 2010, the United States had already invested $4 billion into researching AWS with a further $18 billion earmarked for autonomy development through 2020 (Boulanin and

Table 1. Lethal AI arms race, by the numbers

	Intent		Capacity			Expertise				
	Resolve to Develop AWS	Lethal Citizen Trust in AI[a]	2018 Defense Spending[b] (Billions)	2017-2021 Projected Drone Spending[c] (Billions)	2017 GDP[d] (Trillions)	Number of AI Companies[e]	1997-2017 AI-Related Publications[f]	AI-Related Patents and Patent Applications[g]	AI Talent[h]	Top AI Talent[h]
United States	High	25%	649	17.5	19.4	2,028	369,588	133,941: 279,145	28,536	5,158
China	High	70%	250	4.5	12.2	1,011	327,034	55,868: 66,508	18,232	977
Russia	High	40%	61	3.9	1.5	17	*	*	*	*
South Korea	High	17%	43	1.9	1.5	26	52,175	69,158: *	2,664	*
European Union	Mixed	29%**	281	8**	17.3	859**	425,166**	45,521**: 233,050	41,459**	5,111**

*Data not available. **Data only partially available on some European Union (EU) member-states. Figures are under-estimates based on the combined data for all available EU member-states.

Source notes: [a](Ipsos, 2018); [b](SIPRI, 2019), [c](Statista, 2019); [d](World Bank, 2019); [e](CISTP, 2019b); [f](CISTP, 2019c); [g]The first figure is the number of patents held by each country in 2014, later figures not available due to the processing time of patent applications (Shoham et al., 2018). The second figure is the total number of AI-related patents applications by each country as of March 2019 (IPlytics GmbH, 2019). [h]AI talent refers to experts with the expertise to develop new AI innovations. AI top talent refers to leading international AI researchers in the top 10 per cent of their field, as measured by research impact and citations (CISTP, 2019a).

Verbruggen, 2017). Despite already owning over 20,000 autonomous vehicles, the United States is projected to spend $17 billion on drones through 2021, including 3,447 new unmanned ground, sea, and aerial systems (Gettinger, 2018; Statista, 2019).

In the military AI expertise race, the United States started before the opening gun even went off by investing $1 billion in 'strategic computing' back in 1983, and since then has consistently outspent its competitors (Boulanin and Verbruggen, 2017). In addition to having the most AI companies in the world, the United States has the most AI-related publications for a single country, the most AI patent applications and accepted AI patents, as well as the largest pool of talented AI researchers, including those in the top ten per cent of their field, more than any other single country in the world (CISTP, 2019a, 2019b, 2019c; IPlytics GmbH, 2019; Shoham et al., 2018).

China

China is the clear rising contender in lethal AWS and AI development and has outlined in its 'Next Generation Artificial Intelligence Development Plan' that it intends to utilize AI on the battlefield in association with AWS (China State Council, 2017; Kania, 2017). With a combination of 70 per cent citizen trust in AI (the highest of the 24 countries surveyed) and the heavy pressure it can exert on companies to transfer technology to the state, it is unlikely to face significant internal resistance to AWS development (Ipsos, 2018).

China's capacity for weapons development is high with an estimated annual budget of $250 billion and projected spending of $4.5 billion on drone technology by 2021 (SIPRI, 2019; Statista, 2019). Most impressively, Chinese companies have tested swarming technology with over 1,000 synchronized drones (Kania, 2017). However, while some countries, such as South Korea, Israel, and Japan, seek AWS development to augment their soldiers and fill near-term gaps in security, China, with the world's largest army, does not have this problem. This frees China to focus the bulk of its resources on long-term strategic investments in AI.

China publicly plans to become the world leader in AI development by 2030 (China State Council, 2017). China's controversial methods of intellectual property procurement have allowed them to make technological leaps forward in a non-linear fashion. With heavy 'civil-military fusion' investment, China's State Council estimates their AI industries to be worth $22 billion by 2020, $59 billion by 2025, and $150 billion by 2030 (China State Council, 2017; Kania, 2017). By some metrics, China has already taken the lead in AI. Despite lagging in total publications, between 2011 and 2015 Chinese scientists published 41,000 papers on AI, almost double the United States during the same period (Baker, 2017). Further, Chinese investment and financing in AI projects between 2013 and 2018 is estimated to be 60 per cent of the entire worlds funding of such projects, again more than doubling United States investment during the same period (CAICT and Gartner, 2019). However, China does face a problem of top expertise flight as despite having over 18,000 talented AI developers, when it comes to those who rank among the

world's best, the United States and EU each have more than five times as many of the top experts (CISTP, 2019a).

Russia

Despite scoring low across several capacity and expertise metrics, Russia is a leader in the lethal AWS race because it is its most brazen supporter. Russia is openly looking to remove humans from the decision-making loop and does not intend to comply with any international efforts to curtail or ban AWS use in combat (Bendett, 2017; Tucker, 2017). In accordance with Russian programs for the 'Creation of Prospective Military Robotics through 2025' and 'Concept for Deployment of Robotic Systems for Military Use until 2030', Russia plans to have autonomous systems guarding their weapons silos by 2020 and aims to have thirty percent of their combat power to be partially or fully autonomous by 2030 (Bendett, 2017; Moscow Times, 2014).

Russia is acutely focused on near-term hardware development. Despite a comparatively low annual GDP and total budget for defense, Russia is intent on spending almost as much as China on drones by 2021, has a military robotics-focused rearmament budget of $346 billion, and hosts annual conferences on the roboticization of its armed forces (Bendett, 2017; Sputnik News, 2013; Statista, 2019). Their autonomous Uran-9 robotic tank has already been deployed to Syria (Mizokami, 2018).

President Vladimir Putin has publicly stated whoever becomes the leader in AI will 'become the ruler of the world', however, Russian investments in AI are significantly lacking (Bendett, 2017). Even basic AI statistics on Russia are hard to come by and one potential explanation may be that significant development is not happening on a comparable scale. Despite having at least ten research centers dedicated to AI use in warfare, Russia's annual domestic military spending on AI is estimated to be as low as $12.5 million annually, just 0.01 per cent of the unclassified AI budget for the United States military (Bendett, 2017, 2018). International sanctions may be part of the problem as Russia has been forced to cut its defense budget by 7 per cent in 2017, 3.2 per cent in 2018 and estimated 4.8 per cent for 2019 (Kofman, 2017).

South Korea

South Korea is a disproportionately strong player in the development of lethal AWS and the world leader when it comes to autonomous sentry weapons. While only 17 per cent of South Koreans trust AI, most have no problems with robots in general (Ipsos, 2018). With a ratio of 631 robots to every 10,000 human workers, they have the highest concentration of robots in the world (Peng, 2018). Facing slowing population growth, South Korea is looking for automation to move beyond industrial use and into the military realm as it currently relies on mandatory conscription to fill the ranks of its army.

Despite being under an American security umbrella, South Korea's own weapons development capacity remains high, spending $41 billion on defense annually (SIPRI, 2019). With a credible threat to the North, their primary concern has been the development of static, defensive AWS. The world's first stationary autonomous robotic turret, the Samsung SGR-A1, was developed in South Korea in 2006 (Parkin, 2015). Beyond that, Korean arms manufacturer DoDAAM developed the Super aEgis II, a long-range sentry gun turret that can autonomously detect, track, and engage targets – and in a troubling trend of proliferation, has reportedly sold this technology to the United Arab Emirates and Qatar (Parkin, 2015).

AI expertise cultivation is a major focus in South Korea. Two days after their world champion Go player, Lee Sedol, was defeated by Google's DeepMind AlphaGo AI system, South Korea pledged nearly $1 billion towards AI research (Peng, 2018). With close to 70,000 AI patents, more than 50,000 publications on AI, and more than 2,000 AI experts, South Korea is major player on the world stage (Bode and Huelss, 2018; CISTP, 2019a, 2019c; Shoham et al., 2018). South Korea aims to remain competitive globally by opening six new AI-focused schools by 2020 (Peng, 2018).

The European Union

The EU, with a combined GDP soon to be the largest in the world and several leading weapons manufacture member-states, has the potential to become the global leader in AWS development (World Bank, 2019). At present, the EU's focus has been on industrial AI and robotics. The largest impediment to the EU becoming a dominant actor in lethal AWS development is the mixed intent of its members. France, Germany, the United Kingdom (UK), Sweden, and Italy all are developing autonomous military robotic systems, however some members remain undecided, and Austria has even joined calls for a ban on AWS use (Boulanin and Verbruggen, 2017; Campaign to Stop Killer Robots, 2018). Further complicating the issue, the European Parliament holds the position that humans must always maintain decision-making control over lethal weapons systems (European Parliament, 2018).

With the second largest combined defense budget in the world, totaling $281 billion, and projected spending on drone procurement of at least $8 billion by 2021, the EU has the capacity to develop world-class AWS hardware (SIPRI, 2019; Statista, 2019). Some individual EU member-states are heavyweight contenders in their own regard. France alone outspends Russia and South Korea on defense with more than $63 billion budgeted annually and further has stated that AI will be a major part of their military strategy (Peng, 2018; SIPRI, 2019). Germany spends $49 billion annually on defense and has produced an 'Active Defense System' with an automated reaction time of less than a millisecond (Boulanin and Verbruggen, 2017; SIPRI, 2019). Autonomy is a core component of the Italian army modernization plan and it spends more than $27 billion on defense annually (Nones and Marrone, 2012; SIPRI, 2019). The UK is the second largest exporter of weapons in the world, spends more than $49 billion annually on defense, and is investing heavily in swarming drone technology (Boulanin and Verbruggen, 2017; SIPRI, 2019).

The EU has surpassed even the United States on some AI metrics. EU member-states published the most AI-related papers, with more than 425,000 total, and have the second highest figures when it comes to AI patent applications, with more than 233,000 (CISTP, 2019c; IPlytics GmbH, 2019). Further, the EU has the most AI talent and top talent in the world, with over 41,000 and 5,100 respectively, coming just from Germany, France, the UK, Spain, and Italy alone (CISTP, 2019a). If the combined expertise and capacity of the member-states can be pooled effectively through the new European Defense Fund, the EU could emerge as the dominant actor in the AI and AWS arms race.

Ending the artificial intelligence arms race with a ban on killer robots

As the AI arms race rages on, the stakes remain high yet public debate is lacking. Sixty-one per cent of citizens polled across more than twenty countries oppose the development of lethal AWS, and yet billions of their tax dollars are being spent on their development each year (CSKR, 2019). France, Germany, and others have advocated use of the Convention on Certain Weapons (CCW) process to develop 'Possible Guiding Principles' as a code of conduct to encourage AWS development to stay in accordance with existing international law (Convention on Certain Weapons, 2018). Beyond that, 28 states have called for a ban on killer robots, and further the Non-aligned Movement and a group of African states desire to negotiate a new international treaty to set limits on robotic killing. Previous weapons bans, from chemical and biological weapons to landmines and cluster munitions, have been effective policy tools which significantly curtailed the use of these problematic weapons. While the United States is not currently in a position to lead with its ill-fated 'America First' policy, the EU and other forward-thinking countries should attempt to set solid global norms and push for a ban on the use of AWS now. China announced last year that it wishes to ban the battlefield use of AWS, but not their development and production. This could serve as a basis for coalition negotiations with the rest of the world and would represent a key step forward in preventative security governance (Garcia, 2018).

Note

1. Other notable contenders in the AI arms race are India, Israel, and Japan, see 'Dark Horses in the Lethal AI Arms Race' for more information (Haner, 2019).

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