The new killer drones: understanding the strategic implications of next-generation unmanned combat aerial vehicles

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Unmanned aerial vehicles (UAVs), popularly known as 'drones', have altered the manner in which military force is applied, particularly in offensive counterterrorism operations. Although the vast majority are small systems designed for intelligence, surveillance and reconnaissance purposes, a significant number of larger UAVs are armed and can most accurately be described as unmanned combat aerial vehicles (UCAVs).[1] Over the past decade, their use has generated an important and necessary public debate over a range of humanitarian, doctrinal and ethical issues, much of it focused specifically on targeted killings.[2] As scholars, strategists and policy activists evaluate the costs and consequences of current systems, however, the strategic and technological ground is shifting underfoot.

Rapid technological advances resulting in intelligent machines for commercial and household use have also generated a similar wave of robotic systems for military applications. Small hand-launched UAVs provide military units with unprecedented situational awareness, unmanned ground vehicles can disarm improvised explosive devices, and unmanned underwater vehicles can clear mines or even engage an opponent's maritime assets. These important developments have the potential to greatly enhance the effectiveness of military operations, albeit primarily at a tactical level. The deployment of larger unmanned aerial systems, given the combination of their speed, range and armaments payload, is likely to have not only tactical ramifications but also broader strategic implications. In a number of countries, work is well under way to create a new generation of highly manoeuvrable armed unmanned aircraft with low radar observability and greater levels of autonomy in anticipation of operations in contested airspace.

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1 A number of terms have been used to describe these platforms, including 'unmanned aerial vehicle' (UAV), 'remotely piloted aircraft' (RPA) and 'uninhabited systems'. This article will use the terms 'UCAV' and 'armed drone' interchangeably. For an important and thorough discussion of terminology, see Damian Killeen and David Jordan, 'RPAS: future force or force multiplier? An analysis of manned/unmanned platforms and force balancing', *Air Power Review* 16: 3, Autumn–Winter 2013, pp. 10–28.

2 Bradley Strawser, ed., *Killing by remote control: the ethics of an unmanned military* (Oxford: Oxford University Press, 2013); John Kaag and Sarah Kreps, *Drone warfare* (Cambridge: Polity, 2014); Stephanie Carvin, 'The trouble with targeted killing', *Security Studies* 21: 3, 2012, pp. 529–55; Peter Lee, 'Rights, wrongs and drones: remote warfare, ethics and the challenge of just war reasoning', *Air Power Review* 16: 3, Autumn–Winter 2013, pp. 30–49.

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As the push to develop more advanced unmanned systems continues, it is worth pausing to reflect on the set of factors driving the dramatic growth in the deployment of the current generation of UCAVs. What impact will trends such as contested airspace, UCAV proliferation and greater autonomy for unmanned systems have on the strategic utility of second-generation combat drones? The next generation of armed drones, whether it be large highly complex and capable 'exquisite' systems or swarms of smaller platforms, will almost certainly have implications that have yet to be fully understood. This article first briefly reviews the operational and strategic aspects of drone use over the past decade before describing the contextual changes that are altering the operating environment for unmanned combat aerial systems and inspiring a new generation of UCAVs. I will then go on to discuss a number of strategic implications related to this new generation, before concluding with a broader net assessment of these changes.[3]

Current usage

For over a decade, remotely piloted UCAVs such as the MQ-1 Predator and MQ-9 Reaper have provided battlefield commanders with unprecedented situational awareness by virtue of powerful on-board sensors and significant loitering ability, circling the terrain at altitude to provide real-time intelligence, surveillance and reconnaissance (ISR) data. In an armed surveillance capacity, drones offer an ability to identify, target and destroy (or 'find, fix and finish') adversaries with a single platform. Military leaders maintain that the tactic of liquidating suspected terrorists and insurgents with missile strikes from drones has degraded the adversary's leadership structures and reduced its operational efficacy by forcing it to adapt to the constant threat of air strikes. The use of unmanned technology allows for the application of military force in situations where the risk to military personnel—or the political exposure involved in retrieving a downed air crew—is considered to be unacceptably high.[4] It is argued that precision-guided munitions and long loitering times allow operators to better distinguish legitimate targets from civilian sites and to minimize collateral damage in ways that manned aircraft or ground operations cannot—although critics strongly disagree with this characterization and point to numerous instances of civilian casualties caused by strikes from drones.[5]

On the battlefield, drone operators have been used as forward air controllers—identifying targets and directing strikes for fast-moving fighters and bombers—or for limited close air support. During the NATO-led operation in Libya, UCAVs performed surveillance, identified targets and carried out strike sorties.[6] Predator

3 Next-generation UCAVs are likely to shift the current moral, ethical and legal discussion from killing remotely to a question of deploying lethal autonomous robots (LAR). While that is a highly relevant and important debate, the present article will focus solely on the political and strategic aspects of unmanned systems.

4 See Guy Edwards, 'Military autonomous and robotic systems', *Air Power Review* 16: 3, 2013, pp. 50–71.

5 See Daniel Byman, 'Why drones work', and Audrey Kurth Cronin, 'Why drones fail', both in *Foreign Affairs* 92: 4, July–Aug. 2013, pp. 32–43, pp. 44–54.

6 Doug Richardson, 'Armed Predator sees action over Libya', *Jane's Missiles and Rockets*, 4 May 2011; Spencer Ackerman, 'Libya: the real US drone war', *Wired*, 20 Oct. 2011, http://www.wired.com/2011/10/predator-libya/, accessed 29 May 2015.

and Reaper drones were used actively in Afghanistan by the United States and United Kingdom, and Israel deployed both the Reaper and other armed UCAVs during its 2008–2009 Cast Lead operation in Gaza.[7] Unmanned systems have also been deployed for base defence missions involving surveillance and engaging targets outside the perimeters of military installations.[8] During raids conducted by ground forces, UCAV operators can remain more intently focused on providing overwatch for the mission below than fast-moving jets whose pilots must devote more of their attention to the surrounding airspace and flying the aircraft.[9]

Through satellite data links, UCAVs are often flown in so-called remote-split operations (RSO): a ground team in theatre launches and retrieves the drone while a flight crew from a ground control station assumes in-flight operation. Owing in part to the unavoidable delay or 'latency' involved when using satellite links and the limited, downward-looking 'soda straw' view afforded to operators, the accident and mishap rate for unmanned systems remains considerably higher than for manned aircraft.[10] On the other hand, some have convincingly argued that such concerns are exaggerated, given that situational awareness for manned aircraft also relies primarily on electronic on-board systems, and the risk of mid-air collisions may be further reduced with existing sensor technologies.[11] Despite these challenges, rotating flight crews based thousands of miles from the combat theatre are able to maintain a greater number of extended combat air patrols in a fashion that inherently and dramatically improves situational awareness. In addition, airmen experience something close to a commuter-style war-fighting deployment, although this is offset by the psychological demands of constantly shifting from combat situation to suburban reality.[12]

In many cases, remotely piloted systems have provided a counterterrorism policy option where the only alternative is often inaction, particularly in areas where ground operations are logistically or politically challenging. While far from a complete or optimal solution, aerial strikes may nevertheless serve to keep such threats at manageable levels by culling the target group's leadership, hindering its operations and reducing its overall effectiveness.[13] Missions using unmanned platforms—particularly if conducted covertly by the intelligence community—reduce the likelihood of domestic political opposition at home and provide greater

7 Ann Rogers and John Hill, *Unmanned: drone warfare and global security* (London: Pluto, 2014), pp. 38–40.

8 Caitlin Lee, 'UAVs play growing role for base defense in Afghanistan', *Jane's Defence Weekly*, 7 May 2013.

9 Author's interview with a former MQ-1 Predator operator, Oct. 2013.

10 United States Air Force Scientific Advisory Board, *Operating next-generation remotely piloted aircraft for irregular warfare*, report SAB-TR-10-03 (Joint Base Andrews, Camp Spring, MD, April 2011), p. 32; Jeremiah Gertler, 'US unmanned aerial systems', Congressional Research Service report R42136 (Washington DC, 3 Jan. 2012).

11 Killeen and Jordan, 'RPAS: future force or force multiplier?', pp. 19–20. A recent study offers further support for the argument that the additional benefit to situational awareness with a human in the aircraft is minimal in an age when aerial engagements are decided primarily with electronic sensors beyond visual range. See John Stillion, *Trends in air-to-air combat: implications for future air superiority* (Washington DC: Center for Strategic and Budgetary Assessments, 2015).

12 See Elisabeth Bumiller, 'A day job waiting for a kill shot a world away', *New York Times*, 29 July 2012; Dave Blair, 'Ten thousand feet and ten thousand miles', *Air and Space Power Journal* 26: 3, May–June 2012, pp. 61–9.

13 The broader strategic benefits of leadership decapitation and precision strike are debatable. For a thoughtful discussion, see Michael Aaronson and Adrian Johnson, eds, *Hitting the target: how new capabilities are shaping international intervention*, Whitehall report 2-13 (London: Royal United Services Institute, March 2013).

freedom for the administration to act, given the more ambiguous legal authorizations under which civilian entities such as the US Central Intelligence Agency (CIA) operate. The US reliance on the CIA to carry out drone strikes has been a highly controversial aspect of UAV operations, owing to its questionable legal foundations, unclear rules of engagement and a general lack of transparency.[14]

Contrary to official statements, civilian deaths associated with drone strikes have occurred regularly and cause resentment among local populations.[15] This strategic 'blowback' undermines the trust needed to wage successful counterinsurgency campaigns and can lead to further radicalization and the creation of 'accidental guerrillas'.[16] Furthermore, drone strikes are perceived negatively outside the US, creating political and diplomatic pressures that weaken popular support for military action. The United Nations has issued several reports critical of the practice of targeted killings on legal and ethical grounds, and an international movement has formed to limit the further development of unmanned systems.[17] Nevertheless, the perceived tactical advantages of drones have prompted a growing number of state and non-state actors to develop or acquire unmanned systems which then become a military threat. Viewed broadly, therefore, drone deployment can adversely affect long-term strategic interests when one takes into account the blowback from local populations and international organizations, increased drone proliferation and the establishment of potentially undesirable usage precedents.

Changing strategic context

Drones became a prominent element in military capability largely because of the unique tactical requirements of irregular warfare, which included the need to distinguish combatants from civilians coupled with an operational framework and technological infrastructure that could affordably provide persistent ISR and an exceedingly short 'kill chain' from target identification to weapons launch. However, this situation is expected to change profoundly. US Defense Secretary Chuck Hagel reflected a widespread view among defence professionals when he announced in February 2014 that the Defense Department planned to 'slow the growth in its arsenal of armed unmanned systems that, while effective against

[14] Gordon Lubold and Shane Harris, 'Exclusive: the CIA, not the Pentagon, will keep running Obama's drone war', *Foreign Policy*, 5 Nov. 2013. Other sources describe a more complex command chain in which missions are conducted by US Air Force personnel, but under the auspices of the CIA.

[15] Stanford Law School and NYU School of Law, *Living under drones: death, injury, and trauma to civilians from US drone practices in Pakistan* (Stanford, CA, and New York, 2012); Benjamin Medea, *Drone warfare: killing by remote control* (New York: Verso, 2012); Micah Zenko, 'America's 500th drone strike', Council on Foreign Relations, 21 Nov. 2014, http://blogs.cfr.org/zenko/2014/11/21/americas-500th-drone-strike, accessed 29 May 2015.

[16] Michael J. Boyle, 'The costs and consequences of drone warfare', *International Affairs* 89: 1, Jan. 2013, pp. 1–29; David Kilcullen and Andrew McDonald Exum, 'Death from above, outrage down below', *New York Times*, 17 May 2009; Leila Hudson, Colin S. Owens and Matt Flannes, 'Drone warfare: blowback from the new American way of war', *Middle East Policy* 18: 3, Fall 2011, pp. 122–32.

[17] Christof Heyns, *Report of the UN Special Rapporteur on extrajudicial, summary or arbitrary executions*, Report A/68/382 (New York, 13 Sept. 2013); Ben Emmerson, *Report of the UN Special Rapporteur on the promotion and protection of human rights and fundamental freedoms while countering terrorism*, Report A/68/389 (New York, 18 Sept. 2013).

insurgents and terrorists, cannot operate in the face of enemy aircraft and modern air defences'.[18] The current generation of drones is also becoming less relevant as the United States slowly rebalances its military posture towards the Asia–Pacific region and renews its focus on high-intensity warfare. Even against less advanced adversaries, UCAVs are projected to become increasingly vulnerable as smaller regional actors gain greater access to advanced air defence capabilities.[19]

Slow-moving and non-stealthy drones are easily targeted by ground-based air defences or an adversary's combat aircraft. The supporting infrastructure for UCAV operations, from ground control installations to GPS and communications satellites, is susceptible to attack and could affect remote operations.[20] The tremendous advantages gained through net-centric warfare also leave those same networks vulnerable to disruption or interception. Hostile environments for UCAVs therefore include not only kinetic threats to the physical security of system components, but also data jamming, electromagnetic disturbances and cyber threats that hinder the ability of unmanned platforms to send or receive data.[21] A research team from the University of Texas even demonstrated the ability to commandeer a drone by sending it a false GPS signal, a technique known as 'spoofing'. While difficult, such techniques might eventually become sufficiently advanced to spoof not only GPS signals but also targeting and weapons release commands.[22]

Despite these drawbacks, drones have become an achievable symbol of technological prowess. Nearly 80 countries are now pursuing some type of unmanned aircraft—almost a doubling over the past decade.[23] Approximately two dozen states are developing longer-range armed drones, and this number is also projected to increase.[24] Michael Boyle has compared this new drone arms race to the diffusion of military aircraft, which spread from industrialized nations to developing ones initially for the prestige an air force bestowed but eventually because 'military aviation was creating dramatic strategic consequences, either by resetting the terms of competition for existing rivalries or by introducing a degree of uncertainty into regional balances of power'.[25] Just within the NATO alliance, the United Kingdom, France, Italy and the Netherlands have already joined the United States in operating the MQ-9 Reaper, prompting the formation of a NATO Members

[18] Chuck Hagel, 'FY15 budget preview', 24 Feb. 2014, http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1831, accessed 29 May 2015.

[19] Carlo Kopp, 'Proliferation of advanced air defence systems', *Defence Today* 8: 2, 2010, pp. 24–7; John Reed, 'Predator drones useless in most wars, top Air Force general says', *Foreign Policy*, 19 Sept. 2013, http://foreignpolicy.com/2013/09/19/predator-drones-useless-in-most-wars-top-air-force-general-says/, accessed 29 May 2015.

[20] André Haider, *Remotely piloted aircraft systems in contested environments: a vulnerability analysis* (Kalkar, Germany: NATO Joint Air Power Competence Centre, Sept. 2014).

[21] Brien Alkire, James G. Kallimani, Peter A. Wilson and Louis R. Moore, *Applications for Navy unmanned aircraft systems* (Santa Monica, CA: RAND, 2010), pp. 26–7; United States Air Force, *RPA vector: visions and enabling concepts 2013–2038* (Washington DC, Feb. 2014), pp. 29–31; Haider, *Remotely piloted aircraft systems*, pp. 71–4.

[22] Craig Whitlock, 'US documents detail al-Qaeda's efforts to fight back against drones', *Washington Post*, 4 Sept. 2013.

[23] US Government Accountability Office, *Nonproliferation: agencies could improve information sharing and end-use monitoring on unmanned aerial vehicle exports* (Washington DC, July 2012), p. 9.

[24] Lynn E. Davis, Michael J. McNerney, James S. Chow, Thomas Hamilton, Sarah Harting and Daniel Byman, *Armed and dangerous: UAVs and US security* (Santa Monica, CA: RAND, 2014), pp. 7–9.

[25] Michael Boyle, 'The race for drones', *Orbis* 59: 1, Winter 2015, pp. 76–94.

User Group to review tactics, techniques and procedures.[26] Other industrialized states and a host of developing nations are racing to develop their own indigenous drone programmes.

A number of factors determine how far the spread and eventual adoption of innovative military technology will extend, including the financial demands of the new capability and the organizational capacity required to incorporate the technology into military operations.[27] Even so, these technologies may become more accessible to smaller states or non-state actors with the advent of additive manufacturing (commonly referred to as 3D printing), steadily improving computer processing power, and the inevitable spread of technological expertise.[28] The only regulatory framework currently applicable to UAV technology is the 1987 Missile Technology Control Regime (MTCR), which mentions unmanned systems together with cruise missiles and covers UAVs with ranges of at least 300 kilometres and payloads over 500 kilograms. A number of countries currently producing armed drones, most notably Israel and China, are not members of the MTCR and therefore fall outside its purview.[29]

A global security landscape filled with large numbers of technologically advanced armed unmanned systems may have significant implications for the future of armed conflict. Robert Work and Shawn Brimley suggest that as precision-guided munitions and low-cost unmanned systems proliferate, 'the impetus toward greater battlefield mass is more likely to be reflected in greater numbers of unmanned systems rather than in more or larger manned units or crewed systems'.[30] They theorize that small but wealthy and technologically advanced states could eventually build autonomous UCAVs in significant numbers, a development that could 'decouple military power from the population base, traditionally a significant measure of military power'.[31]

The steady march towards greater autonomy in unmanned aerial platforms appears almost inevitable given current and expected operational demands. The sheer volume of intelligence data generated by a single combat air patrol requires a substantial number of analysts for its processing, exploitation and dissemination. Partially as a consequence of this, a report by the United States Defense Science Board noted that 'the Air Force has declared that its most critical staffing problem is manning its unmanned platforms'.[32] Also, the communications infrastructure required for remote operation and transmission of intelligence data back to analysts

[26] Chris Pocock, 'NATO user group for Reaper UAVs established', *Aviation International News*, 10 Oct. 2014.

[27] See Michael C. Horowitz, *The diffusion of military power* (Princeton: Princeton University Press, 2010); Samuel Brannen, Ethan Griffin and Rhys McCormick, *Sustaining the US lead in unmanned systems* (Washington DC: Center for Strategic and International Studies, Feb. 2014), p. 7.

[28] Harrison Menke, 'Commentary: Africa's window into the drone age', *Defense News*, 20 Jan. 2014. For a discussion of the terrorist threat from UAVs, see also David Hastings Dunn, 'Drones: disembodied aerial warfare and the unarticulated threat', *International Affairs* 89: 5, Sept. 2013, pp. 1237–46.

[29] Davis et al., *Armed and dangerous*, pp. 9–10; Sarah Kreps and Micah Zenko, 'The next drone wars', *Foreign Affairs* 93: 2, March–April 2014, pp. 68–79; William Wan and Peter Finn, 'Global race on to match US drone capabilities', *Washington Post*, 4 July 2011.

[30] Robert Work and Shawn Brimley, *20YY: preparing for war in the robotic age* (Washington DC: Center for a New American Security, Jan. 2014), pp. 8–9.

[31] Work and Brimley, *20YY*, p. 33.

[32] Defense Science Board, *The role of autonomy in DoD systems* (Washington DC, July 2012), p. 57.

is costly and inefficient, with bandwidth requirements projected to increase dramatically.[33] In anti-access environments where adversaries have deployed advanced air defences, these data transmission linkages become an exploitable vulnerability, either through the disruption of data flow or through the detection of electronic emissions from UCAVs that are otherwise less likely to be observable.

Part of the solution to both personnel demands and survivability requirements, according to US Defense Department planners, includes on-board automated analysis of raw intelligence data using pattern recognition algorithms to filter or prioritize the information, thereby reducing overall data volume and the time needed for human analysts to process it.[34] Newer sensors such as Argus-IS from BAE Systems include 'on-board embedded image processing algorithms' to reduce bandwidth requirements.[35] This type of automatic filtering will continue to evolve alongside improvements to existing automated navigational and operational tasks aboard unmanned systems. An autonomous capability, on the other hand, will go beyond pre-programming of system operations and, as a Pentagon report states, 'into laws and strategies that allow the system to self-decide how to operate itself'.[36] Using machine-based artificial intelligence, systems can select their own behaviour in response to changing mission parameters 'to reach a human-directed goal'. Not only will increased autonomy reduce personnel and operating inefficiencies, defence planners view it as a 'crucial' attribute for maintaining tactical advantage on the battlefield.[37]

The current state of the art in aircraft and missile technology already incorporates a significant degree of machine control. Today's advanced fly-by-wire fighter aircraft rely upon on-board computers to such an extent that flight controls and targeting options are already highly automated: pilots manage on-board systems rather than physically control them. Using computers and electronic sensors to gather information earlier and more quickly, pilots seek to dominate the so-called OODA (observe–orient–decide–act) loop. In the near future, adversaries may leverage advanced technologies to 'operate faster than a defender can observe the activity, orient himself, decide how to respond and act on that decision'.[38] Processing and acting on information more quickly than the adversary—'getting inside the enemy's decision loop'—is seen as crucial to winning future conflicts, and greater machine autonomy may be decisive.

Forming a precise definition for autonomy remains a surprisingly difficult exercise. Referring to an entire armed drone as 'autonomous' is convenient, but it may instead be more helpful to describe the balance of decision-making authority between human and machine during each of the four steps of the OODA loop.

[33] United States Air Force, *RPA vector*, pp. 63–7.

[34] Defense Science Board, *The role of autonomy*, p. 38.

[35] BAE Systems, 'Autonomous real-time ground ubiquitous surveillance imaging system', fact sheet, http://www.baesystems.com/product/BAES_162772/ARGUS-IS, accessed 29 May 2015.

[36] US Department of Defense, *Unmanned systems integrated roadmap FY2013–2038*, report 14-S-0553 (Washington DC, Dec. 2013), p. 67.

[37] US Department of Defense, *Unmanned systems*, p. 67.

[38] Thomas K. Adams, 'Future warfare and the decline of human decisionmaking', *Parameters* 41: 4, Winter 2011–12 (repr. from issue 31: 4, Winter 2001–02), pp. 5–19.

Some systems exhibit greater autonomy when navigating or tracking targets but require greater human involvement for target acquisition and engagement.[39] In a recent working paper, Paul Scharre and Michael Horowitz distinguish between *semi-autonomous weapons*, which seek out particular targets or classes of targets based on a human operator's decision to launch, *human-supervised autonomous weapon systems*, which are able to independently select specific targets but with human monitoring and the possibility of intervention, and fully *autonomous weapon systems*, which select and engage targets without any human involvement.[40]

Modern missile technology already incorporates high levels of self-guidance: examples include Britain's Brimstone missile, Norway's Joint Strike Missile and Israel's loitering Harpy anti-radiation cruise missile. Even more complex decisions regarding target acquisition are made by defensive systems such as South Korea's SGR-A1 stationary armed sentry robot, the American ship-based MK 15 Phalanx close-in weapons system, and Israel's Iron Dome anti-missile battery. Perhaps the most advanced of all is the Aegis combat system found on many US Navy vessels and in some of its allies' navies: an integrated command and control weapons system able to independently identify, target, prioritize and engage a large number of surface and airborne threats. Such systems would be considered autonomous weapons systems according to one recently proposed definition: 'An autonomous weapon system is a weapon system that, based on conclusions derived from gathered information and preprogramed constraints, is capable of independently selecting and engaging targets.'[41] Nevertheless, the most analytically useful distinction may be the sliding scale of autonomy offered by Scharre and Horowitz, which emphasizes the level of human involvement during targeting and weapon release. The Brimstone missile, launched by a human operator against a class of targets but capable of independently choosing its specific target, would be considered a semi-autonomous system, whereas the Aegis system, capable of identifying, targeting and launching weapons without human interference in its most automated 'casualty' mode, might be considered a fully autonomous platform.

A few military observers view even greater machine autonomy as an almost unavoidable eventuality, and some believe that an autonomous weapons arms race is already under way.[42] Strategist Thomas Adams has reasoned that since humans are arguably the most valuable, vulnerable and difficult component to replace in any weapons system, adapting military systems to accommodate human needs—such as protective armour or sustainable g-forces—entail suboptimal design compromises that provide strong incentives for not having a human aboard.[43] The OODA loop, argues US Air Force Captain Michael Byrnes, 'implicitly reveals

[39] William C. Marra and Sonia K. McNeil, *Understanding 'the loop': autonomy, system decision-making, and the next generation of war machines*, Lawfare research paper no. 1-2012 (Washington DC: Lawfare Institute, May 2012), pp. 18–20.

[40] Paul Scharre and Michael Horowitz, *An introduction to autonomy in weapon systems*, working paper (Washington DC: Center for a New American Security, Feb. 2015), p. 16.

[41] Rebecca Crootof, 'The killer robots are here: legal and policy implications', *Cardozo Law Review*, vol. 36 (forthcoming), 2015, pp. 101–76.

[42] John Markoff, 'Arms guided by software, not people, stirs fear', *International New York Times*, 12 Nov. 2014.

[43] Adams, 'Future warfare', p. 7.

that the "art of flying" is actually a cyclical processing activity'; the superior computing ability of machines will eventually allow them to outperform humans in every step of the loop.[44] Unlike their human counterparts, machine pilots do not require constant training to remain proficient and would be instantly ready for combat even after long periods of inactivity.

Even if artificial intelligence technology is unable to completely match human aptitude for decision-making and complex pattern recognition, the astonishing pace of technological advancement and the exponential growth in microprocessor computational capacity is likely to produce a militarily useful equivalent.[45] Particularly in an era when aerial engagements can often be decided beyond visual range, autonomous drones may have remarkable tactical utility even if the natural instincts and unconventional thinking of pilots remain beyond the limits of computer coding. A 2011 report from the UK Development, Concepts and Doctrine Centre (DCDC) noted that 'it is likely that automated systems will be developed that are broadly capable of the same levels of functionality as self-aware autonomous systems', with civilian sector applications leading the way.[46] Reflecting an intent to keep humans in the loop, a Pentagon directive of 2012 mandated that autonomous weapons systems in the United States be designed to give operators 'appropriate levels of human judgment over the use of force'.[47]

Implications

The confluence of these three contextual developments—contested airspace, widespread UAV proliferation and greater autonomy—will bring about a profoundly altered set of operational parameters for second-generation unmanned systems. Slow persistent overhead ISR and armed reconnaissance missions that rely on extended loitering over targets will be less feasible in contested environments. While persistence has been the most advantageous characteristic of unmanned systems to date, other considerations may become more relevant as tactical applications for second-generation combat drones may increasingly (and paradoxically) resemble those of manned aircraft.

These tactical considerations begin with design characteristics. The current fleet of UCAVs was designed for endurance, with generous wingspans for maximum lift and small, fuel-efficient motors that sacrifice speed and agility for extra time on-station. In contested environments, however, speed, stealth and manoeuvrability are necessary to enhance survivability. As a result, the principal design requirement for second-generation drones is likely to shift from persistence to penetrating ability. The current primary tactical use of UCAVs—loitering over a target in an ISR, forward air control or close air support role—will become

[44] Michael Byrnes, 'Nightfall', *Air and Space Power Journal* 28: 3, May–June 2014, pp. 56–7.

[45] P. W. Singer, *Wired for war: the robotic revolution and conflict in the 21st century* (New York: Penguin, 2009), pp. 97–8.

[46] Development, Concepts and Doctrine Centre (DCDC), *The UK approach to unmanned aircraft systems*, Joint Doctrine note 2/11 (Shrivenham, March 2011), p. 6–7.

[47] US Department of Defense, 'Directive number 3000.09: Autonomy in weapons systems' (Washington DC, 21 Nov. 2012).

less feasible owing to increased risk from an adversary's anti-access/area denial capabilities and the aircraft's own performance parameters.

Second-generation UCAVs will instead focus on penetrating strike, penetrating ISR, suppression of enemy air defences and close air support tasks. In addition, autonomous UCAVs could be used for air-to-air and air-to-ground combat, either together with other unmanned systems or in a 'loyal wingman' role under the control of a manned fighter aircraft employing it in a counter-air capacity or as a flying auxiliary magazine for additional armaments to be fired by the manned fighter. In this concept of operations, UCAVs act in conjunction with manned aircraft as an integrated force multiplier. Smaller autonomous drones could be networked into a coordinated swarm formation, using numbers and extreme manoeuvrability to overwhelm and defeat an adversary's air defences.[48]

Two distinct but far from mutually exclusive directions are therefore possible for next-generation UAV systems: a limited number of more capable drones with better survival capacity using speed, stealth and counter-measures; and a swarm of low-cost 'attritable' platforms able to overwhelm an adversary's defences. The diverging design requirements inherent in these two approaches imply dissimilar tactical applications—not only from each other, but from the current generation of drones. For now, the Pentagon's vision assumes that the 'limited development of new capabilities will likely focus on smaller numbers of higher end platforms capable of operating in more contested air environments'.[49] While the exact system requirements for the US Navy's unmanned carrier-launched airborne surveillance and strike (UCLASS) programme remain the source of some dispute, Northrop Grumman's candidate, the X-47B, successfully took off and landed from a carrier in 2013 without human intervention. Other large next-generation low-observability unmanned systems include BAE Systems' 'Taranis' demonstrator, the 'Neuron' prototype developed by a European conglomerate led by France's Dassault, and China's 'Lijian' (Sharp Sword) drone.[50]

For these second-generation UAVs, stealthy design features and more powerful engines will improve their ability to penetrate and evade enemy air defences with evasive manoeuvres involving g-forces far beyond those human pilots can endure. Rather than sending a steady stream of full-motion video to commanders, ISR data may need to be stored on board for analysis upon return so as to reduce detectable electronic signal emissions and avoid transmission jamming.[51] In contested environments, persistent ISR to distinguish combatants from civilians will be a less relevant mission than it has been in the current irregular warfare context. The compact stealthy design, manoeuvrability, increased fuel requirements and reduced data transmissions may result in an aircraft with quite different tactical functionality from today's Predators and Reapers.

[48] See Haider, *Remotely piloted aircraft systems*, p. 101; Alkire et al., *Applications for navy unmanned aircraft systems*, pp. 42–8; United States Air Force, *RPA vector*, pp. 49–56.

[49] US Department of Defense, *Unmanned systems*, p. 5.

[50] BBC News, 'China "flies first stealth drone"—reports', 22 Nov. 2013; David Pearson, 'European defense firms' drone push remains elusive', *Wall Street Journal*, 8 Oct. 2013.

[51] Alkire et al., *Applications for navy unmanned aircraft systems*, pp. 26–7.

The future, however, may lie in smaller drones. As Robert Work and Shawn Brimley have argued, 'large quantities of low-cost, expendable unmanned systems can be produced to overwhelm enemy defences with favourable cost–exchange ratios … making survivability a characteristic not of any individual platform but of a swarm of systems'.[52] While a networked swarm of semi-autonomous drones may prove to be an effective and technologically achievable capability for some states, others might utilize a low-tech version of this tactic to overwhelm defences. As unmanned systems proliferate and become more capable, UCAVs may be needed to counter an opponent's unmanned systems. If artificial intelligence and computing speeds continue to advance, inhabited aircraft and their human pilots will eventually become less manoeuvrable and less capable of rapidly processing battle space information compared with autonomous craft. Information regarding an opponent's positions, numbers and aerial tactics can be shared instantaneously among networked and self-learning autonomous UAVs, which can adapt their tactics accordingly in almost real time.[53] In such an eventuality, the deployment of significant numbers of autonomous UCAVs would become a tactical necessity. Regardless of their potential missions, second-generation drones are likely to be tailored to specific tasks that will only vaguely resemble current usage.

In an operational perspective, humans may soon act as managers 'on' or 'over' the decision-making loop, rather than in it. The next evolutionary step in air power, according to military thinkers such as US Air Force General Mike Hostage and retired Lieutenant-General David Deptula, will be the creation of an integrated and coordinated 'combat cloud'. As envisioned by Deptula, the combat cloud would be a distributed, all-domain 'system of systems' that uses highly automated and seamless data transfer to integrate ISR, strike and enabling capabilities.[54] Given the tactical mission set envisioned for second-generation UCAVs, a cloud combat with machine-based command and control coordination may be an operational imperative as the pace of future conflicts develops at speeds which make it impossible for human input to be made at every decisional node. As one officer predicted: 'The trend towards the future will be robots reacting to robot attack, especially when acting at technologic speed … as the loop gets shorter and shorter, there won't be any time in it for humans.'[55] The extent to which the current generation of UCAVs constitutes a revolution in military affairs (RMA) is debatable, but an autonomous swarm of armed drones controlled by something similar to a next-generation Aegis combat system would surely transform the nature of warfare.[56]

One potential consequence of this reliance on machine-based war-fighting is that when military interventions do not place personnel in harm's way, decision-

[52] Work and Brimley, *20YY*, p. 28.

[53] Byrnes, 'Nightfall', p. 54; see also Edwards, 'Military autonomous and robotic systems', p. 54.

[54] Robbin Laird, 'The next phase of air power: crafting and enabling the aerospace combat cloud', *Second Line of Defense*, 11 Feb. 2014. See also David J. Blair and Nick Helms, 'The swarm, the cloud, and the importance of getting there first', *Air and Space Power Journal* 27: 4, July–Aug. 2013; Matthew R. Hipple, 'Cloud combat: thinking machines in future wars', *Proceedings Magazine* 138: 7, July 2012, pp. 48–53.

[55] Singer, *Wired for war*, p. 64.

[56] For a discussion on UAVs and RMA, see Rogers and Hill, *Unmanned*, pp. 133–48; also Edwards, 'Military autonomous and robotic systems', p. 63.

makers may exercise less restraint in using force abroad and democratically elected leaders may be less susceptible to public pressures.[57] Sarah Kreps and Micah Zenko have argued that drones 'create a particular moral hazard by keeping pilots away from danger', but the permissive environments in which drones have operated generally pose little risk to manned aircraft and a number of other low-risk options such as cruise missiles have long been available.[58] Rather, it appears that persistent ISR combined with the ability to strike quickly with the relatively limited blast radius of the AGM-114 Hellfire missile better explains the widespread use of drone strikes on the battlefield. It is not the absence of risk to personnel, but perhaps faith in the quality of the intelligence, an ability to observe a target over time, and the seemingly surgical nature of precision-guided munitions that encourage the tactic despite the risk of civilian casualties. Less than two decades on from the Clinton administration's 1998 cruise missile attacks on suspected terrorist camps in Afghanistan and Sudan, there now exists an even more precise means of conducting long-range strikes.

The air campaign over Pakistan and Yemen which since 2002 has targeted suspected terrorists and militants using remotely piloted craft, despite the availability of ground troops and manned aircraft, 'suggests that the use of force is totally a function of the existence of an unmanned capability—it is unlikely a similar scale of force would be used if this capability were not available', in the words of a 2011 DCDC report.[59] Given the roughly comparable tactical requirements for carrying out precision strikes in either Pakistan or Afghanistan and low risk to manned aircraft in either of those countries, it appears that political considerations such as plausible deniability have also been a strong motivator for deploying UCAVs. Not only did the United States refrain from acknowledging the use of unmanned aircraft in Pakistan, this ambiguity also allowed Pakistani leaders to tacitly acquiesce in politically unpopular counterterrorism operations over its territory in a manner that might not have been possible with strikes from manned aircraft.[60] As Rogers and Hill succinctly put it: 'Because drones *can* be used for targeting individuals in ambiguous territory under ambiguous legal justification, they *are* so used.'[61]

This ambiguity might be leveraged tactically during hybrid warfare operations. Unmanned and unmarked combat systems could be used to covertly sabotage an adversary's infrastructure while maintaining some semblance of plausible deniability. The ability to inflict physical costs on an adversary while retaining the option of disowning an unsuccessful operation constitutes a powerful coercive weapon. For many leaders, the potential gains of such an action might outweigh the risks, particularly in low-intensity conflicts. The temptation to use military force may become more intense with the advent of next-generation UCAVs, particularly against opponents with less substantial air defences.

[57] See e.g. Boyle, 'The costs and consequences of drone warfare'; John Kaag and Sarah Kreps, 'Drones and democratic peace', *Brown Journal of World Affairs* 19: 11, Spring–Summer 2013, pp. 1–13.
[58] Kreps and Zenko, 'The next drone wars'.
[59] DCDC, *The UK approach to unmanned aircraft systems*, pp. 5–9.
[60] For more on this complex relationship, see Stanford Law School and NYU School of Law, *Living under drones*, pp. 15–17.
[61] Rogers and Hill, *Unmanned*, p. 64 (emphasis in original).

Conversely, offensive military operations against industrialized adversaries with modern air defences may in fact be dependent on second-generation drones with much greater range than manned aircraft. In a possible high-intensity conflict in the western Pacific, American aircraft carriers might be forced to remain beyond the range of Chinese anti-ship ballistic missiles. Unmanned carrier-based strike aircraft would be able to strike targets in situations in which manned aircraft lacked the range or on-station endurance to be effective.[62] Penetrating UCAVs could be used both to destroy enemy air defences prior to manned sorties and also, against less advanced countries, for strikes without requiring a coordinated effort to destroy air defences beforehand. The benefits of such raids, particularly if high-value targets are involved, will be weighed against the risk of losing expensive platforms; the calculus may be deemed acceptable in view of the absence of risk to military personnel and the possibility of avoiding conflict escalation were the UCAVs to be intercepted.

This perceived willingness of policy-makers to use unmanned aircraft is also precisely the reason why second-generation UCAVs could become a valuable deterrent asset. Not only do they represent a highly credible threat owing to the absence of risk to personnel, they offer a scalable long-range precision strike capability that may be able to evade integrated air defences. Particularly against a potential adversary deploying anti-access capabilities with the objective of deterring intervention, UCAVs could provide a credible force projection option that might negate the deterrent effect of that adversary's capabilities.[63]

So credible could this option be, in fact, that deterrence postures might be less of an impediment to military action if both sides deployed unmanned systems, particularly regarding the regional deployment of high-intensity war-fighting assets meant to create precisely such a deterrent effect. The deterrence logic and proper response to the destruction of unmanned aircraft remain unclear, as does the escalatory chain in machine-on-machine combat. Without any loss of life or captive pilots, an aggressor state may be less interested in escalation if its unmanned aircraft are shot down while violating another's airspace. The state sustaining the violation to its sovereignty, however, may react as strongly to an unmanned intruder as to a similar intrusion by a manned aircraft.[64] In general, the absence of personnel may afford states a greater degree of flexibility in choosing their response to such episodes, making these situations less predictable and therefore less stable.[65] Perhaps UCAV skirmishes would simply provide

[62] Jan Van Tol, *AirSea battle: a point-of-departure operational concept* (Washington DC: Center for Strategic and Budgetary Analysis, 2010), pp. 61–71; James D. Perry, 'Unmanned air systems and deterrence', in Adam Lowther, ed., *Thinking about deterrence* (Maxwell, AL: Air University Press, 2013), pp. 249–69.

[63] Perry, 'Unmanned air systems and deterrence'.

[64] This point was suggested by an anonymous reviewer.

[65] When the citizens or military personnel of a state are killed by another state, there is political pressure to hold the offending state accountable for its actions as well as a strategic interest in some type of retaliatory action in order to demonstrate resolve. With unmanned systems, it becomes far easier to probe defences or test the reaction of an adversary without risking the potential for escalation. It is also possible, however, to envisage a situation in which a state (or non-state actor, for that matter) might wish to use the downing of an unmanned system as a basis for further escalation. Historically, the loss of unmanned aircraft has not generated pressure for retaliatory measures—one might compare the diplomatic fallout after U-2 pilot Gary Powers was shot down over the Soviet Union in 1960 with the lack of any serious diplomatic response when a US intelligence-gathering drone was downed over China just four years later. For an excellent history of UAVs, see Thomas

another—albeit more aggressive—means of signalling; but they might also foster a lower threshold for initiating hostilities that could easily and rapidly escalate into a large-scale conflict. Unlike other uninhabited weapons systems, such as cruise or ballistic missiles, that threaten passively until launched, UCAVs are able to actively penetrate airspace and threaten attack without actually engaging a target.

Second-generation UCAVs could therefore prove to be a source of considerable instability. Smaller armed drones may be viewed as a low-cost and low-risk means of probing defences and testing an adversary's responses. Along contested borders—between Pakistan and India, China and Japan, Israel and Palestine—unmanned aircraft have already been used to violate airspace, increasing the risk of miscommunication and inadvertent escalation.[66] The current generation of UCAVs constitute only a mildly destabilizing military technology, remaining as they do inherently vulnerable to air defences, but the next generation of armed drones may present a far greater threat.

On the other hand, the application of military force in a contested environment represents a higher organizational and financial commitment compared to permissive environments, perhaps raising the threshold for military action and limiting the capricious use of force. Whereas UCAVs have hitherto operated almost exclusively in permissive airspace, truly contested environments would be less conducive to the loitering tactics currently used by UCAVs to identify and track targets. As armed drones become more capable and complex, they also become increasingly valuable, more limited in number, and repositories of more sensitive equipment whose loss to an adversary would be detrimental to the deploying state. Furthermore, it has become clear over the past several decades that the application of air power alone has rarely proved effective in achieving the political goals prompting the use of military force in the first place, perhaps making the use of UCAVs a more politically expedient but strategically indistinguishable option from that of manned aircraft.

Whether autonomous offensive weapons systems are able to meet the minimum requirements to be considered lawful remains a contentious academic debate that lies beyond the scope of this article, but the political and strategic ramifications of deploying legally dubious systems may be profound.[67] Many observers consider the current counterterrorism doctrine of targeted killing with unmanned systems to be a violation of the laws of armed conflict; to deploy an autonomous system to perform similar tasks would serve only to magnify the violation. Limiting autonomous targeting to machine-on-machine engagements aimed at aircraft, armoured vehicles, missile batteries and other clearly military assets may alleviate some of this tension, although such a targeting policy is more easily implemented in the context of high-intensity conflicts than in irregular ones. Currently, the use of armed drones has generated political resistance, but not yet to levels that impose any real strategic costs.

P. Ehrhard, *Air Force UAVs: the secret history* (Arlington, VA: Mitchell Institute Press, 2010).

66 Boyle, 'The race for drones', pp. 89–90.

67 See Noel Sharkey, 'Saying "NO!" to lethal autonomous targeting', *Journal of Military Ethics* 9: 4, 2010, pp. 369–83; Jeffrey S. Thurnher, 'Legal implications of fully autonomous targeting', *Joint Forces Quarterly* 67: 4, 2012, pp. 77–84; Crootof, 'The killer robots are here'.

A net assessment

Second-generation UCAVs are almost certain to have different tactical uses from their predecessors. A new strategic context is emerging, characterized by humans managing a machine-driven decision-making loop rather than actively but remotely controlling armed drones, new war-fighting doctrines for machine-on-machine combat, and a number of strategic implications that remain unclear and potentially destabilizing. The first generation of unmanned systems emerged when the strategic context and operational requirements fitted perfectly with the system's capabilities. With no shortage of irregular conflicts in sight, demand on this basis may remain high. However, their tactical utility appears limited to such low-intensity operations in permissive environments, and the most prominent application of the platform—targeted strikes against individuals—is a potential political and strategic liability.

If fully developed and deployed, second-generation UCAVs will face a different set of operational requirements from first-generation systems, entailing a significantly altered cost–benefit equation. Building large unmanned platforms for high-intensity conflicts in contested environments entails replacing the simplistic Predator with something more similar in its complexity to a modern fifth-generation fighter aircraft. This raises a difficult set of questions regarding affordability, functionality and the level of autonomy desired. It is far from certain that second-generation systems will be able to balance these cross-cutting interests in a way that is strategically advantageous. Answering the question 'Why unmanned?' with first-generation drones was simple: persistence beyond that which was possible with a human in the cockpit. For second-generation systems, the answer remains less obvious, but appears to be a combination of reducing risk to personnel and countering any enemy UCAVs that are manoeuvrable or stealthy enough to defeat manned aircraft.

The strategic cost–benefit equation may not favour removing the pilot from the aircraft unless low-cost UCAV swarms with dependable machine autonomy are developed. Otherwise, the cost of exquisite systems, particularly in an austere fiscal environment, will limit numbers and raise the operational risks of deploying them. This question is highly relevant, as the United States is expected to launch an acquisition programme for a sixth-generation 'air dominance' aircraft within the next few years. Air Force officials are seriously contemplating an unmanned platform and are reportedly 'very interested' in autonomy.[68] One recent analysis astutely observed that future political support for UAVs would depend on whether it is 'worth the time and effort to develop UAVs to do the same jobs as manned aircraft in contested environments'.[69] Support may also rest on the outcome of the continuing societal debate over unmanned systems and machine autonomy.

The ethical dimension of killing from a distance has been debated repeatedly through the arc of history as weaponry has developed from arrows to intercon-

[68] Aaron Mehta, 'What's next: USAF lays groundwork to replace fighter, tanker fleets', *Defense News*, 14 Sept. 2014.

[69] 'Staying the course: US UAVs advance on a shoestring', *Jane's Defence Weekly*, 23 July 2013.

tinental ballistic missiles.[70] Many of the moral and political objections to current unmanned systems focus primarily on policy decisions regarding how the platform has been employed rather than on the inherent characteristics of the technology itself. While well intentioned, the conflation of the use of armed drones with the tactic of targeted killing has muddled rather than clarified an important discussion regarding the strategic and sociological impact of next-generation UCAVs and machine autonomy. Images of fully autonomous drones targeting individuals without human approval would indeed be unsettling—and most likely of questionable military value as well. Deploying autonomous UCAVs for high-intensity warfare may be less problematic but nonetheless give rise to a unique set of strategic challenges, simply because of the qualitative differences from current systems.

Throughout history, new weapons technologies have often been developed and deployed without a precise concept of operations being ready to accompany them. Even so, there is a distinct lack of consensus surrounding the possible uses of second-generation UCAVs, with options ranging from a 'loyal wingman' function to autonomous penetrating strike to a coordinated swarm of small autonomous drones. The potential second- and third-order effects of autonomous weapons systems may be sufficiently far-reaching to warrant the further development of operational concepts for second-generation UCAVs before proceeding. Currently, the technology appears to be moving forward more rapidly than the military doctrines intended to govern its use.

[70] See Christopher Coker, *Warrior geeks: how 21st century technology is changing the way we fight and think about war* (London: Hurst, 2013).