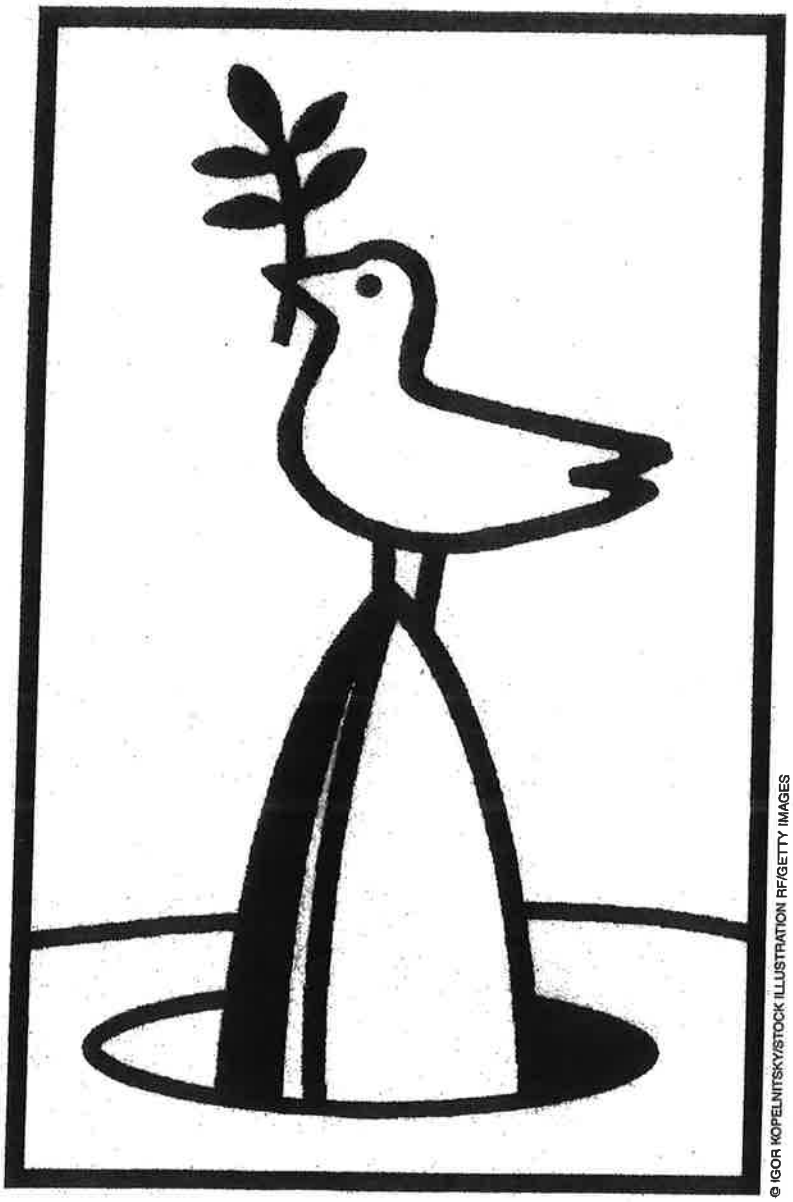
Predators or Plowshares?

Arms Control of Robotic Weapons

ROBERT SPARROW

With the development of the General Atomics MQ-1 Predator, robotic weapons came of age. The operations of this Unmanned Aerial Vehicle (UAV) in Iraq, Afghanistan, Pakistan, and northern Africa in the last few years have given us a glimpse of the future of high-tech war [6], [14], [24]. It is a future in which thousands of miles separate those firing weapons from those whom they kill, in which joystick jockeys have replaced pilots and soldiers, and in which the psychological barriers to killing are greatly reduced by the distance between weapon operators and their targets. Perhaps more importantly, it is a future in which wars are more likely, in which decisions about when weapons are fired and who they are fired at are increasingly in the hands of machines, and in which the public has little knowledge of—or control over—what is being done in its name. Finally, it is a future that is likely to come about not because it represents a better, less destructive, way of fighting war but because the dynamics driving the development of unmanned weapon systems (UMS) are likely to



© IGOR KOPELNITSKY/STOCK ILLUSTRATION RF/GETTY IMAGES

Digital Object Identifier 10.1109/MTS.2009.931862

1932-4529/09/$25.00©2009IEEE

> Robotic weapons may lower the political costs of going to war by promoting the illusion that war can be fought without casualties.

dictate that they be used more and more often.

Now that we have had a glimpse of this future, it is time to begin thinking about whether—and how—we might avoid it by adopting an arms control regime designed to limit the development and deployment of robotic weapons.

Out of Harm's Way

Arguments for arms control are most important when there is a real temptation to develop the weapons they concern. From a military perspective at least, the advantages of UMS are myriad. Remotely piloted systems may help keep some human beings "out of harm's way" by distancing weapons operators from the theater of conflict [31]. They also greatly reduce the "fog of war" by making possible real-time surveillance of the battlespace, which in turn allows lethal force to be used in a more discriminating fashion.

In suggesting that there may be reasons to consider arms control of UMS, I am in no way denying the military utility of these systems nor even that they offer some prospect of rendering some aspects of armed conflict "more ethical." However, the danger I wish to highlight here is that each nation's unrestrained pursuit of these advantages may result in a situation in which every nation is worse off than they would have been if none had set off on this path.

Psychological Distance

The first and in some ways the most obvious reason for concern about the development of unmanned systems is the possibility that they will undercut warfighters' respect for human life by facilitating "killing at a distance" [41]. It is now possible for the operators of the Predator to fly an entire combat tour in Iraq or Afghanistan without ever leaving Nevada and to kill people they have only ever encountered as pixels on a computer screen. The geographic and psychological distance between the operators and those they target may make it significantly easier for them to make the decision to kill [39]. However, the force of this objection to the development of robotic weapons is greatly mitigated when we consider the nature of what the use of such weapons might replace. Shelling from a battleship miles offshore or conducting area bombing from a B-52 hardly involves much contact with, or respect for, the individuals one is killing. Our willingness to tolerate these forms of warfare suggests that concerns about "remote control killing" are not, in themselves, sufficient justification for arms control.

Increased Risk of War

A more powerful reason for considering arms control is the danger that the development of unmanned systems will dramatically reduce the threshold of conflict and will increase the risk of accidental war.

At the strategic level, the development of robotic weapons may lower the political costs of going to war by promoting the illusion that war can be fought without casualties [6], [16], [19]. It is clear that the possibility of removing American warfighters from the front line of combat is one of the main factors driving interest in UMS in the United States [7], [12], [16], [17], [18, p. 14], [23], [26], [31], [32], [34], [37]. In part, this goal reflects the morally admirable desire to save the lives of U.S. warfighters. However, it is difficult to avoid the suspicion that the desire to minimize the risks to U.S. personnel also stems in part from a perception that the American public has a low tolerance for casualties, which negatively impacts on the ability of the United States to project force abroad [5], [15], [20, p. 79], [26, p. 77]. If it becomes possible to project military power and engage an enemy in combat using a force consisting mainly of UMS, governments may be much more willing to go to war [5, p. 26], [27], [28].

UMS will also lower the threshold of conflict at the strategic level by decreasing the amount of time available to nations to determine whether an attack is imminent, or even under way, and also how to respond if it is.

Part of the U.S. military's interest in UMS, and especially UAVs and Unmanned Undersea Vehicles (UUVs), stems from the belief that it will eventually become possible to deploy unmanned systems for much longer periods and at a greater tempo of operations than manned systems [31]. By taking the human being out of the system, unmanned systems partially decouple the limits of the system from the limits of its operators. UAVs can be smaller, faster, fly higher (or lower), and conduct longer and more dangerous missions than manned systems [40]. For instance, because the operators of Predator and Global Hawk UAVs work in shifts, these systems are capable of near continuous operation and are limited only by the need to refuel and maintain the aircraft [10]. Researchers in the United States are currently working on providing UAVs with the capacity to undergo in-flight refueling [9], [21] in order to further increase the range and extend the period of operations of these systems. Similarly, it is hoped that UUVs will eventually be capable of missions in shallower waters than manned submersibles [13].

The development of long-range UMS capable of extended operations may make it possible for some states to maintain a permanent armed presence just outside the airspace and territorial waters of their potential enemies, in the form of "loitering" UMS. These forces might be capable of carrying out a devastating attack in a fashion that would allow their target very little time to respond. If an attack is suspected or seems imminent, there is a brief window of opportunity between possible contact and destruction available to determine whether one is under attack by UMS. This places states under significant pressure to mobilize their own forces, and increases the chance that war will occur in error.

The widespread use of UMS may also increase the amount of contact between opposing forces during peacetime and so further multiply the opportunities for an accident or incident to escalate to conflict. Thus one can envision that, in the future, not only will strategic rivals patrol the limits of each other's territories with squadrons of UAVs, Unmanned Surface Vehicles (USVs), and UUVs ready to attack at a moment's notice. But these systems may, in turn, be shadowed by further groups of systems poised to destroy them. In these circumstances, accidents or even mere uncertainty about the intentions of an enemy may trigger a full-scale conflict. Placing robots in space is likely to greatly exacerbate these difficulties [1].

The risk of accidental war triggered by the activities of UMS is only likely to increase in the future because the logic of the development of unmanned systems clearly points to their eventual deployment in "fully autonomous" mode. Despite the insistence of military spokespeople that autonomous robots will never be allowed to kill human beings [16], there are significant reasons to doubt that this promise will be kept. The satellite links and other communications infrastructure necessary to operate UAVs remotely are an obvious weak point in the operations of these systems and are consequently a predictable target for the enemy's countermeasures. Those systems that can continue to operate in the absence of these links have obvious military advantages.

> Because the operators of Predator and Global Hawk UAVs work in shifts, these systems are capable of near continuous operation.

Indeed, systems that do not involve a human operator may possess advantages even where the robustness of communications is not at issue. The limits of the human nervous system serve as a constraint on the capacities of manned systems. In a limited range of domains at least, computers are capable of assessing a situation and making a decision faster and more accurately than human beings [2, pp. 6–7]. As the technology involved in robotic weapons improves, eventually we will reach a point where whenever a manned and an unmanned weapon system go into combat against each other, the odds will strongly favor the unmanned system [1], [5]. Once this point is reached, warring nations will have to field autonomous weapons systems or accept a severe military disadvantage. This prospect also establishes a significant incentive for advanced industrial powers to work towards the development of systems capable of reliable combat operations in the absence of a human operator.

Once autonomous weapons systems come into use then the decision about whether or not to open fire in a particular situation will be in the hands of machines. The risk will then exist of an accidental war being triggered by the decisions of one or more autonomous weapon systems.

UMS Arms Control

The implications of a weapons system for the threshold of conflict and/or the risk of accidental war are familiar grounds upon which to argue a case for arms control. I believe that they establish a strong case for arms control of robotic weapons. There are also additional, less familiar, reasons to be concerned about future developments in UMS. The advent of robotic weapons makes it significantly easier for governments to avoid public scrutiny of their military adventures [16], [27], [28]. The use of robotic weapons is likely to greatly increase the likelihood and extent of asymmetric warfare. The prospect of autonomous weapon systems raises questions about the appropriate locus of responsibility for deaths caused by their operations [3], [11, p. 4], [25], [38] and the extent to which such systems will be capable of discriminating between legitimate and illegitimate targets according to the Law of Armed Conflict [8], [35]. However, reasons of space prevent me from discussing these further here.

In order to try to avoid a reduction of the threshold of conflict, to reduce the risk of accidental war, and to avert these other outcomes, I believe that it is time to consider development of an arms control regime to govern the deployment and development of robotic weapons. The obvious place to start would be to negotiate restrictions on the range of these systems and the length of the missions they are capable of in order to reduce the likelihood of them being used in "loitering" roles. Alternatively, should this prove impossible (as noted above, the extended range

> Designing an effective arms control regime for unmanned systems will involve profound challenges.

and endurance of UMS are a primary driver of military interest in these systems) the peacetime deployment of armed UMS within a certain range of the sovereign territories of other nations should be prohibited. At the very least, there should be a limit on the destructive capacity of the weapons carried by long-range UMS in order to avoid reducing the threshold of conflict by rendering nations too vulnerable to pre-emptive attacks by UMS. More controversially, I believe it would be sensible to try to work out some way to resist the drive to develop and deploy autonomous weapon systems. The advent of these systems would raise so many difficult ethical and policy issues that we should approach the possibility with extreme caution, if at all. Yet, as discussed above, the dynamics pushing towards the development and application of these systems are extremely powerful. If we are to have any choice in this matter at all, I believe that it is essential for roboticists, ethicists, and policy makers to begin thinking about this issue now [4], [36].

Control Will Be Difficult to Achieve

Preventing the development of autonomous weapons systems would require regulating research. Unfortunately, arms control of UMS research will not be easy to achieve. Many of the technologies involved in robotic weapons are "dual use." Much of the research that goes on in computer science and engineering departments in universities, into how to play robot soccer, pattern recognition, or search-and-rescue robotics, has obvious military applications. Any plausible arms control regime intended to include research into UMS will need to be able to delineate a category of prohibited research (perhaps the integration of artificial intelligence and weapons systems?) without capturing so much of the research that goes on in universities as to make compliance impossible. While this is obviously an extremely demanding requirement, it is worth observing that existing arms control regimes, for instance those governing chemical and biological weapons, confront and manage—to some extent at least—similar problems.

There is a further difficulty involved in monitoring the capacities of robotic weapons, which is arguably unique to this project. Unlike other weapons systems, the capacities of an unmanned weapon system are likely to be as much a function of its software as its hardware. Two weapon systems with the same engines, hydraulics, armament, and sensors may have very different capacities depending upon their programming.

Moreover, as long as they can develop an accurate simulation of the performance of the system's hardware, it may be possible for engineers to continue researching software for a weapons system without requiring any physical interface with the actual device. Having developed and tested new software in simulation, they might then radically improve the performance of the system simply by updating its programming. Designing an effective arms control regime for unmanned systems will therefore involve profound challenges, as verifying the capacities of systems and/or preventing weapons testing will be extremely difficult. This danger itself may serve as an argument for instituting arms control in relation to robotic weapons sooner rather than later.

Motivation for Controls

In one important regard, it is probably too early to expect these arguments for arms control to have much impact. The U.S. currently enjoys such an overwhelming superiority in arms and military technology—including robotic weapons—compared to any of its potential enemies that it has little incentive to enter into negotiations about the capacities of its weapon systems. However, this superiority may well be challenged over the next two or three decades, especially in the area of unmanned systems, which may be easier to develop and manufacture using commercial off-the-shelf components than other weapon systems. China, for instance, has a vigorous UAV development program. Russia also has a significant capacity to design, manufacture, and operate UAVs. It is also possible that the technology and experience required to manufacture and field UMS will disperse as a result of the flourishing arms trade in systems manufactured by Britain, Israel, Europe, and other states. It would therefore be unwise to conclude that the U.S. will always maintain the commanding lead in the area of unmanned systems technology that it currently possesses. If another nation should become capable of flying a Predator-type UAV around the skies of North America or loitering a UUV in the waters offshore of the continental U.S., then the issues I have raised here will suddenly become as urgent for U.S. policy makers as they are likely to be for other nations well before that time.

There is now a growing literature on the ethics of unmanned weapon systems. Much of this literature is critical, highlighting the many difficult issues these systems—and

especially autonomous weapon systems—raise. However, most of these discussions settle for calling for more ethical debate rather than arms control. I hope that by explicitly making the case for arms control in this context I can encourage other participants in the debate to clarify whether they have the courage of their convictions. Without arms control of robotic weapons, the future I outlined at the outset of this piece seems inevitable. With a concerted effort to achieve arms control, there is perhaps a small chance that we will be able to overcome the military logic that would hand over the fighting of war to robots in favor of the human need for peace and security.

Author Information

The author is a Senior Lecturer in the School of Philosophy and Bioethics, Faculty of Arts, Monash University, Victoria 3800, Australia.

References

[1] T.K. Adams, "Future warfare and the decline of human decision-making," *Parameters: U.S. Army War College Quart.*, pp. 57-71, Wint. 2001-2002.

[2] R.C. Arkin, *Governing Lethal Behavior: Embedding Ethics in a Hybrid Deliberative/Reactive Robot Architecture*, Mobile Robot Laboratory, College of Computing, Georgia Institute of Technology, Atlanta, GA, 2007.

[3] P.M. Asaro, "Robots and responsibility from a legal perspective," *IEEE Int. Conf. Robotics and Automation*, Rome, Italy, 2007.

[4] P.M. Asaro, "How just could a robot war be?," in *Current Issues in Computing And Philosophy*, P. Brey, A. Briggle, and K. Waelbers, Eds. Amsterdam, Netherlands: IOS, 2008.

[5] C. Beal, "Briefing: Autonomous weapons systems - Brave new world," *Jane's Defence Weekly*, vol. 33, no. 6, pp. 22-26, 2000.

[6] B. Bender, "Attacking Iraq, from a Nev. Computer," *Boston Globe*, p. A6, Apr. 3, 2005.

[7] R. Boland, "Developing reasoning robots for today and tomorrow," *Signal*, vol. 61, no. 6, pp. 43-46, 2007.

[8] J. Boronstein, "The ethics of autonomous military robots," *Studies in Ethics, Law, and Technology*, vol. 2, no. 1, 2008.

[9] R. Braybrook, "Drones: Complete guide, *Armada Int.*, vol. 31, no. 3, pp. 1-36, 2007.

[10] A. Butler, "Global Hawk UAV supports border ops in Iraq," *Aviation Week & Space Technology*, vol. 166, no. 11, p. 56, 2007.

[11] J. S. Canning, *A Definitive Work on Factors Impacting the Arming of Unmanned Vehicles*. Washington, DC: Dahlgren Division Naval Surface Warfare Center, 2005.

[12] R.E. (Col.) Chapman, "Unmanned combat aerial vehicles: Dawn of a new age?," *Aerospace Power J.*, vol. 16, no. 2, pp. 60-73, 2002.

[13] Department of the Navy, *The Navy Unmanned Undersea Vehicle (UUV) Master Plan*, 2004; http://www.navy.mil/navydata/technology/uuvmp.pdf.

[14] S.B. Donnelly, "Long-distance warriors," *Time*, Dec. 4, 2005.

[15] C.J. Dunlap, Jr., "Technology: Recomplicating moral life for the nation's defenders," *Parameters: U.S. Army War College Quart.*, pp. 24-53, Autm. 1999.

[16] S. Featherstone, "The coming robot army," *Harper's*, pp. 43-52, Feb. 2007.

[17] M. Fielding, "Robotics in future land warfare," *Australian Army J.*, vol. 3, no. 2, pp. 1-10, 2006.

[18] S. Graham, "America's robot army", *New Statesman*, vol. 135, no. 4796, pp. 12-15, 2006.

[19] H. Gulam, and S.W. Lee, "Uninhabited combat aerial vehicles and the law of armed conflict," *Australian Army J.*, vol. 3, no. 2, pp. 1-14, 2006.

[20] J.A. Harley, "Information, technology, and center of gravity," *Naval War College Rev.*, vol. 50, no. 1, pp. 66-87, 1997.

[21] H. Hutchinson, "Advances in self-control," *Mechanical Engineering*, vol. 128, no. 12, pp. 20, 2006.

[22] Jane's Intelligence Digest, "U.S. ties with Pakistan under strain," *Jane's Intelligence Dig.*, June 23, 2006.

[23] S. Kainikara, "UCAVs probable lynchpins of future air warfare," *Asia-Pacific Defence Reporter*, vol. 28, no. 6, pp. 42-45, 2002.

[24] R.D. Kaplan, "Hunting the Taliban in Las Vegas," *Atlantic Monthly*, Aug. 4, 2006.

[25] J J. Klein, "The problematic nexus: Where unmanned combat air vehicles and the law of armed conflict meet," *Air and Space Power J. Chronicles Online*, July 22, 2003; www.airpower.maxwell.af.mil/airchronicles/cc/klein.html, accessed Mar. 27, 2007.

[26] A. J. Lazarski, "Legal implications of the uninhabited combat aerial vehicle," *Air and Space Power J.*, vol. 16, no. 2, pp. 74-83, 2002.

[26] W. Legien, C-J. Andersson, and G. Hansen, "UUV and USV: Which 'unmanned' for what task?" *Naval Forces*, vol. 27, no. 3, pp. 44-51, 2006.

[27] P. Marks, "Robot infantry get ready for the battlefield", *New Scientist*, vol. 191, no. 2570, p. 28, 2006.

[28] P. Marks, "Armchair warfare," *New Scientist*, vol. 192, no. 2575, pp. 24, 2006.

[29] T. Moss, "Airshow China: Chinese companies unveil latest UAV designs," *Jane's Defence Weekly*, Nov. 7, 2008.

[30] J. Mustin, "Future employment of unmanned aerial vehicles," *Air and Space Power J.*, vol. 16, no. 2, pp. 86-97, 2002.

[31] Office of the Under Secretary of Defense, *Joint Robotics Program Master Plan FY2005: Out front in harm's way*. Washington DC: Office of the Undersecretary of Defense (AT&L), Defense Systems/Land Warfare and Munitions, 2005.

[32] G.I. Peterson, "Unmanned vehicles: Changing the way to look at the battlespace," *Naval Forces*, vol. 26, no. 4, pp. 29-38, 2005.

[33] D. Richardson, "U.S. increasing armed UAV use in Southwest Asia, reports suggest," *Jane's Missiles and Rockets*, Nov. 3, 2008.

[34] R. Scarborough, "Special report: Unmanned warfare," *Washington Times*, May 8, 2005.

[35] N. Sharkey, "Cassandra or false prophet of doom: AI robots and war," *IEEE Intelligent Systems*, vol. 23, no. 4, pp. 14-17, 2008.

[36] N. Sharkey, "Grounds for discrimination: Autonomous robot weapons," *RUSI Defence Systems*, pp. 86-89, Oct. 2008.

[37] J. Sherman, "The drone wars," *Bull. Atomic Scientists*, pp. 28-37, 2005.

[38] R. Sparrow, "Killer robots," *J. Applied Philosophy*, vol. 24, no. 1, pp. 62-77, 2007.

[39] R. Sparrow, "Building a better WarBot : Ethical issues in the design of unmanned systems for military applications," *Science and Engineering Ethics*, 2009, to be published.

[40] J.M. Sullivan, "Evolution or revolution? The rise of UAVs," *IEEE Technology & Society Mag.*, vol. 25, no. 3, pp. 43-49, Fall 2006.

[41] D.L. Ulin, "When robots do the killing," *Los Angeles Times*, Jan. 30, 2005.