KINGSTON CONFERENCE ON INTERNATIONAL SECURITY
SERIES

ROBOTICS AND MILITARY OPERATIONS

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U.S. ARMY WAR COLLEGE
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UNITED STATES
ARMY WAR COLLEGE
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Carlisle Barracks, PA
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ROBOTICS AND MILITARY OPERATIONS

William G. Braun III
Stéfanie von Hlatky
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Editors

May 2018

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War College's (USAWC) Strategic Studies Institute (SSI) and the NATO Defense College. The partners jointly identify thematic priorities each year, following a careful analysis of emerging trends. Developed with the military community in mind, this conference seeks to examine the implications of international security trends for the Armed Forces of Canada, the United States, as well as NATO allies and partners. A complete listing of past conference themes and proceedings are available on the conference website at the following address: *http://www.queensu.ca/kcis/past-conferences*.

ISBN 1-58487-780-4

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FOREWORD

Each year, partners from academia and the military join to organize the Kingston Conference on International Security (KCIS). This conference is meant to inform debate and advance knowledge in the field of security and defense by identifying priorities in military affairs and convening world-class experts to engage with a series of research questions. Each year, the conference provides in-depth analysis on defense policy priorities with a particular strategy in mind: advancing knowledge by tapping into research and expertise from academia, government, the armed forces, the private sector, and nongovernmental organizations. The partners, the Centre for International and Defence Policy at Queen's University, the U.S. Army War College's (USAWC) Strategic Studies Institute (SSI), the Canadian Army Doctrine and Training Centre, and the North Atlantic Treaty Organization (NATO) Defense College, work together to develop what has become one of the leading international security conferences in North America.

The 2015 KCIS, the 10th annual conference in this series, brought together academics and practitioners from the military, industry, nongovernmental organizations, and international institutions to discuss the challenges posed by robotics and autonomous systems to military operations. This publication is the first in a continuing series to capture the key ideas proffered at the KCIS. The papers presented in this publication provide insight into the drivers influencing strategic choices associated with robotic technology for military applications, and offer preliminary policy recommendations to advance a comprehensive technology investment strategy.

Readers of this publication will come away with a better understanding of the challenges associated with developing robotic technologies for national security uses. The publication busts the myth that "terminator-like" autonomous robots are imminent on current battlefields. Perhaps most importantly, each chapter addresses the ethical implications of employing robotic technology on future battlefields.

DOUGLAS C. LOVELACE, JR.
Director
Strategic Studies Institute and
U.S. Army War College Press

INTRODUCTION

Queen's University hosted the 10th annual Kingston Conference on International Security (KCIS) at the Marriott Residence Inn, Kingston Waters Edge, in Kingston, Ontario, from May 11-13, 2015. The conference was titled "Robotics and Military Operations." The annual KCIS is sponsored, designed, and organized by faculty from Queen's University, the U.S. Army War College (USAWC), the Canadian Doctrine and Training Centre, and the North Atlantic Treaty Organization's (NATO) Defense College. The overall purpose of the conference is to advance scholar-practitioner dialogue and influence senior-level decision-making on strategy and policy-relevant security themes.

In the wake of two extended wars, Western militaries find themselves looking to the future while confronting amorphous nonstate threats and shrinking defense budgets. The 2015 KCIS examined how robotics and autonomous systems that enhance soldier effectiveness may offer attractive investment opportunities for developing a more efficient force capable of operating effectively in the future environment. The conference organizers adopted the premise that it is no longer acceptable to pursue these technologies one program at a time. The military must develop integrated modernization, research and development, and science and technology investment strategies to field effective, low-risk, high-payoff technology solutions over time. The 2015 KCIS explored drivers influencing strategic choices associated with these technologies and offered preliminary policy recommendations geared to advance a comprehensive technology investment strategy.

Conference panels considered the implications of robotics on ethical, legal, operational, institutional, and force generation functioning of the Army across three time-horizons (today, tomorrow, and the future). Particularly in Western Army contexts, the integration of these systems has been limited; the most obvious uses having been in force protection—e.g., counter-improvised explosive device (CIED) or intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) using unmanned aerial vehicle (UAV) functions. As these capabilities expand in both degree and scope, the military will face issues and decisions that will challenge it intellectually, operationally, and ethically. Indeed, the integration of these systems could challenge the military's most fundamental beliefs regarding conflict and the conduct of war. In addition, the resources, both fiscal and human capital, to integrate these systems are limited and require hard choices regarding which specific technologies or capabilities are investment worthy.

The 2015 conference was designed to explore robotics in military operations through a series of seven panel presentations. As an organizing principle, the panels considered two technology time-horizons. The first three panels examined current technologies, employment, and legal or policy standards. This time horizon focused on capabilities employed by forces today, and mature technologies immediately available for military use tomorrow. The next three panels examined future technologies and the ethical, operational-strategic, and force development issues associated with employing them. The final panel synthesized the conference content into specific policy recommendations.

This monograph includes select conference papers, chosen to be published as the inaugural monograph for the KCIS conference series. It contains three chapters, each addressing common themes that resonated throughout the conference. The primary theme is centered on clarifying the debate surrounding robots in military operations. It leveraged accurate use of terminology and a leveling of the audience's understanding of near- and far-term technology maturity. The second, nearly ubiquitous theme is centered on the ethics of using robotic technologies as coercive instruments of war. Finally, nearly every panel provided insight into the pragmatic implications of the presentations, suggesting technologies or trends showing the most promise for resourcing.

The primary theme of the conference contributed to a more informed dialogue regarding robotics in military operations. As with many public dialogue topics, discussions about robotics in military operations lack a common lexicon outside the community of technical experts that have been engaged in it for years. Several authors adopted some variant of Peter Singer's *Wired for War* definition of a robot: a machine with sensors to monitor the environment, processors or artificial intelligence to decide how to respond, and some set of tools to conduct that response.[1] Elinor Sloan in chapter 1 of this volume differentiates between remote controlled, semi-autonomous, and autonomous robots. Alongside the functions robots perform, this categorization clarity contributes to a more refined conversation about the ethical implications of using robots in military operations. A second aspect of clarifying an informed dialogue involves myth busting in the form of pragmatic assessments of the state of robotic technology maturity. Considering the ubiquity of the aspirational futures dialogue that dominates discussions of robots in military operations, in chapter 2, Dr. Simon

Monckton echoes a consistent observation among the scientists and engineers who presented, "a tactically useful and legally permissible system will not be technically feasible for the foreseeable future."[2] Monckton suggests that an Avatar versus Terminator metaphor is the most feasible and desirable to describe robotics in the foreseeable future.

The ethical implications of using robots in military operations only marginally trailed the debate-clarifying theme at the conference. Likewise, each of the chapters in this monograph addresses the ethical implications of robotics in a military context. Most presenters started the ethical implication discussion by acknowledging that most current robotics systems are designed to perform dull, dirty, and dangerous military functions. These applications do not pose the greatest ethical dilemmas. However, fielded systems can be, and have been, adapted to perform lethal functions with relative ease. This aspect of fielding robotic technology, no matter how unsophisticated or banal in function, has the potential of introducing significant ethical dimensions for operators to consider. Therefore, the informed and deliberate consideration of these ethical questions among both scholars and practitioners is occurring behind the operational employment of the systems.

Dr. Elinor Sloan effectively captures the potentially positive ethical components of employing robots in military operations. Robots "will not carry out revenge attacks on civilians, commit rape, or panic in the heat of battle."[3] Dr. Sloan points out that while robots contribute to avoiding the ethical clouding effect of self-preservation and the probability of an anger response, they also present a double-edged ethical concern. Unemotional decision-making, detached from local context and assured of limited collateral damage, may increase the likelihood that lethal force is used. Despite the pragmatic recognition that the employment of autonomous lethal systems is a long way off, the ethical debate regarding their use was clearly the most animated. Two of the most insightful contributions to this debate were proffered by Tony Battista and Elinor Sloan. Tony Battista suggests in chapter 3 that despite semi-autonomous and autonomous systems being future ethical dilemmas, the informed discussion of the ethical issues surrounding their employment is overdue. Elinor Sloan makes the interesting, and potentially contrarian, prediction that arguments constraining the use of lethal autonomous systems are more dependent on a changing ethical environment than any pre-determined ethical reasoning, based on her observation that "America's decades-long ethical prohibition on unrestricted submarine warfare was reversed within hours of the attack on Pearl Harbor."[4]

The pragmatic recommendations about which current and future technologies should be resources were most succinctly captured by Monckton in chapter 2. Dr. Monckton suggests that focusing resources on inexpensive miniaturization, Global Positioning System (GPS), inertial navigation systems (INS), and telecommunication combined with computer processing and memory will provide the most promise over the next decade. He also suggests that longer-range science and technology research focus on probabilistic robotics, networking, and parallel processing to lay the foundation for future advancements.

With that bit of framing, the KCIS team hopes you find the following chapters insightful and engaging.

ENDNOTES - INTRODUCTION

1. P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century*, London: Penguin Books, 2009, p. 45.

2. Simon Monckton, chapter 2 of this volume.

3. Elinor Sloan, chapter 1 of this volume.

4. Ibid.

CHAPTER 1. ROBOTICS AND MILITARY OPERATIONS: POLICY IMPLICATIONS FOR CIVILIAN AND MILITARY LEADERSHIP

Elinor Sloan

The use of armed drones by the United States to target terrorists in places like Pakistan and Yemen is only the most visible move toward the use of robotics in war. Remote controlled aerial surveillance technology dates to at least the mid-1990s, when the well-known Predator unmanned aerial vehicle (UAV) was deployed in the Balkan wars. However, unmanned combat did not appear until the Predator was outfitted with precision missiles in early 2001, making its combat debut that fall in Afghanistan. Since then, and especially after remote controlled systems specifically designed for the use of deadly force started to be fielded, ethical issues have been raised about just how "just" is the use of force by operators thousands of miles from harm's way. Still, with each platform tethered to at least one human that made the fire decision, debate remained relatively subdued.

Today the discussion surrounding robotic warfare has intensified. Technological advances in artificial intelligence and platform performance have raised the prospect that lethal remote controlled systems will become increasingly autonomous. Driven by military competition with its adversaries, who are equally seeking to exploit the military potential of robotics systems, the United States and its allies could field unmanned aerial, ground, and even sea and underwater systems that can make a lethal fire decision without a human directly in the loop. Budgetary and thus personnel constraints, the electromagnetic connection issues of remote controlled platforms, and the increasing speed of warfare are also driving forces. Civilian and military leaders will be challenged to reconcile the desire to do whatever possible to reduce the risk to its warfighters with the necessity of accounting for the laws of armed conflict and broader ethical issues.

CLASSIFYING ROBOTS

In his book, *Wired for War*, Peter Singer argues a machine is a robot if it has three things: sensors to monitor the environment, processors or artificial intelligence to decide how to respond, and some set of tools to conduct that response.[1] What is new today is a move to greater autonomy within the second aspect, the response decision. The progression is from remote controlled to semi-autonomous to potentially fully autonomous capability. The autonomy categories are not set in stone and are better understood as reflecting either end of a continuum, with what the Pentagon calls (in its *Unmanned System Integrated Roadmap*) "self-directed" and "self-deciding" systems at either end of the spectrum.[2]

Self-directed, or semi-autonomous, systems are preprogrammed to perform specific actions, which they then carry out independently of external influence or control. This type of capability is already in existence. Global Hawk UAVs, for example, normally operate as a remote controlled platform "tethered" to a human operator thousands of miles away. However, the Global Hawk has also been designed so it can operate independent of human control within a particular patrol area designated by its human operators. Likewise, "Army unmanned ground systems are being designed to move around the battlefield autonomously," to undertake specific tasks.[3] By contrast, a self-deciding, or fully autonomous, robot would be able to respond to sensed information differently under different circumstances. Rather than having a preprogrammed response or even a preprogrammed goal, a self-deciding machine would be able to seek the optimal solution in unforeseen situations. It would be able to choose the goal that is dictating its path and could adapt and learn from the sensed information around it. That is to say, the robot's actions would originate in it and reflect its ends.[4] A robot's brain, in short, would "act as the human brain does."[5]

Incorporating lethality into the remote-controlled, semi-autonomous, or autonomous schema takes us to the heart of contemporary debate about robotic war. Lethal weapons are already part of remote-controlled and semi-autonomous war. Unmanned combat aerial vehicles (UCAVs) like the well-known Reaper are remotely controlled lethal systems. Cruise missiles can be considered semi-autonomous lethal robots in that they conduct their own search and detect, evaluation, and engage and kill decisions, while still confined by a set of preprogrammed constraints.[6] However, lethality and full autonomy have not yet been combined on the battlefield. Dubbed "killer robots," these potential machines, still at least several years from being fielded, are already the subject of expert meetings at the United Nations in Geneva by groups seeking their ban.

THE DRIVE TO GREATER AUTONOMY

The original driver for unmanned warfare was to assign to a machine those jobs that are dull, repetitive, and dangerous. UAVs allow for the persistent surveillance of territory by a drone that never gets tired or hungry, and that is controlled from a distance by a human that is not at risk. Intelligence, surveillance, and reconnaissance (ISR) is the key task performed by remotely controlled airborne platforms. In the future, naval versions could similarly offer persistent surveillance of territorial waters, locating submarines in place of or in conjunction with traditional, manned, anti-submarine warfare aircraft.[7] Underwater robots also give reach and capability without putting a person at risk. They are used to hunt for mines and explosives and in the future may be used as small scouting submarines for tasks like port security and surveying the depths of the ocean.[8] Unmanned surface vessels, the naval equivalent of UAVs, are being developed and are used by some countries, like Singapore, to protect manned ships. Unmanned ground vehicles (UGVs) are used primarily to carry out the dangerous tasks of demining, such as searching for and destroying roadside bombs. Additional roles include patrolling and guarding military warehouses, airfields, and port facilities; reconnaissance, such as entering buildings in advance of soldiers; and logistics, by aiding and complementing the mobility of soldiers by carrying gear overland.[9]

As attractive as remotely controlled warfare is, there are operational shortcomings. To start, the electromagnetic bandwidth and satellite connection requirements of tethered platforms present a challenge. These systems are at risk of accidental disruption or deliberate enemy targeting using electromagnetic warfare. Adversaries are improving their satellite jamming and cyberattack capabilities, making those platforms that are linked to a controller increasingly vulnerable and potentially unable to complete their missions. Although the United States, for example, has invested heavily in protected, high-bandwidth communications, remote controlled platforms remain limited by their need for robust and reliable communications links to their human operators.[10]

Remote controlled systems also have high manning requirements. The U.S. Air Force estimates one Predator UAV requires a crew of 168 military personnel back home; one Reaper needs a crew of 180 people; and one Global Hawk requires upwards of 300 people. "The number one manning problem in our Air Force is manning our unmanned platforms," points out one U.S. Air Force general.[11] There is, therefore, a personnel-reduction incentive to move from remotely controlled to semi-autonomous robots, which do not require continuous human involvement. The U.S. Navy has already reduced platform manning levels by relying on semi-autonomous robotics, while some U.S. Army leaders believe it may be possible to reduce brigade combat team size by a quarter, from 4,000 to 3,000 troops, by replacing traditional supply convoys with trains of semi-autonomous robot vehicles.[12]

Greater autonomy in military robotics is also driven by the military goal to get inside the enemy's observe, orient, decide, and act (OODA) loop. This loop is the process through which a military commander will go when undertaking a military action. Something that is critical for military victory is getting "inside the loop," which means executing the entire process more quickly than the enemy does. With remotely controlled robots, the human is directly in the loop, whereas in operations involving semi-autonomous machines humans are better characterized as "on the loop," monitoring rather than controlling the actions of several machines at one time. Under such circumstances, humans would delegate tasks out to robots, but the robots would still need human permission to conduct a lethal strike.

However, future war may move at such a pace that it will not be possible for remote operators to make attack decisions quickly enough to counter enemy actions effectively. Humans are likely to become the slowest element in the loop, encouraging the development of machines with the artificial intelligence and processing power to make their own attack decisions. A future force that does not have fully autonomous systems may not be able to compete effectively with an enemy who does have fully autonomous systems.[13]

There can be military operational disadvantages to greater autonomy in warfare. Some military commanders may want to maintain control of weapons on the battlefield, staying connected by a link at all times and having a robot disengage if the link is broken. The fear is that a machine could somehow compromise an operation, perhaps revealing something commanders want to keep quiet.[14] In this regard, there may be situations where using autonomous robots might be considered disadvantageous or unduly risky.[15]

Another shortcoming is that not all robots are created equal when it comes to mission performance. Remotely controlled military robots made their debut in the air, a domain that is generally unencumbered by obstacles. However, even UAVs, in their early versions, were prone to technical failure when dealing, for example, with the dust of Afghanistan. Today, the promises of UGVs are limited by the challenge of negotiating terrain in all-weather circumstances. There are many situations in which a ground robot's performance is not at the level of a human, including driving on snow-covered roads, driving into the sun, and driving in rain or dust storms.[16] Clearly while there are some roles at which robots might be better suited than humans, there are others where humans remain far more talented.[17]

CONDUCT OF WAR

In the last century, military planners eventually integrated the new technology of manned flight into warfighting concepts; so, too, is remote controlled and robotic technology being incorporated into thinking about the conduct of warfare in this century. Remotely controlled platforms were once used almost exclusively to provide ground forces with a view of what was over the next hill. What was already being done by manned aircraft was now being done in a more persistent manner by UAVs and the role was and still is to support ground forces by providing real-time surveillance information about the position of enemy ground forces. In the 2000s, UAVs moved from being a pure ISR platform to one that combined that function with lethal strike. Predators armed with precision munitions were used in close air support of troops on the ground, again much as manned platforms had previously done and continue to do.

More recent warfighting concepts go beyond preexisting doctrine. New ideas include manned-unmanned teaming concepts, or human-system collaboration, about how robotics may be used as a weaponized element of the combined team. One idea being exercised, for example, is remotely controlled platforms providing targeting information directly to manned fighters, which then carry out the strike. Military planners are also thinking about how to integrate unmanned surface vessels into future fleet plans and operations, and UGVs into a future battlefield that combines manned and unmanned platforms.[18]

Remotely controlled platforms have come of age during a period of almost complete U.S. air superiority. Since the end of the Cold War, UAVs (and later, armed drones) have operated in uncontested environments like Bosnia, Iraq, and Afghanistan where there have been no planes or missile systems to threaten the drone. In this sense, armed drones are in their operational infancy. Future planners will need to think about developing tactics for using remotely controlled vehicles in contested environments—that is, air-to-air unmanned combat and, eventually, for combat between unmanned ground, sea, and undersea platforms.

An example that is often given of the doctrinal work that needs to be done is that of Germany's Blitzkrieg. Whereas in the early stages of World War II, Britain and France used tanks in ways that did not change the fundamentals of war, Germany integrated tanks with aircraft to form a new and more powerful means of warfighting. Today, the challenge is to determine how best to fight with military robots. Two doctrinal concepts have already begun to emerge. The "mothership" concept would involve deploying high value robots that are programmed to seek out, achieve an objective, and then return to a centralized command post. By contrast, "swarming" would involve fielding many inexpensive robots that operate independently but synergistically toward a goal. Each robot would in itself have little capability but would be preprogrammed to send a signal should it lock onto an objective, triggering the mass of robots to converge on the target.

Implementing the swarming concept would mark a change in direction in the historical evolution of warfare. For 2 centuries, the battlefield has been progressively emptying out. Humankind went from the levee on mass of the Napoleonic wars, to the smaller yet still very large Industrial Era war machines of World War I and World War II, to the much smaller, more mobile and agile army units of the Information Era. Swarming would represent a reversal in this trend—a return to mass in warfare. Quantity—or mass—is re-emerging as critical for gaining a military advantage.[19]

ETHICAL CONCERNS

As soon as UAVs were armed with precision strike munitions, robotic warfare started to be considered in terms of the laws of armed conflict. Could it be just for a person thousands of miles from harm's way to make a strike decision to kill another human being? The answer is yes when one considers that remotely controlled lethal weapons are just the latest development in the move away from face-to-face battle—from cannon, to artillery, to air-to-ground precision strike by manned aircraft. Nevertheless, the decision to fire must also meet fundamental provisions of the law of armed conflict, especially discrimination and proportionality. Discrimination means the ability to distinguish between military objectives and civilian populations and to limit civilian casualties, while proportionality involves an assessment of whether or not the expected collateral damage of an action is likely to be excessive in relation to the expected gain in military advantage.

A concurrent debate was, and is, whether remotely controlled lethal force makes killing too easy. The thinking is that political leaders may more easily authorize the use of force knowing that aviators are not being put in harm's way, and those controllers and their commanders will be more likely to pull the trigger. However, there is anecdotal evidence that warfare by committee leads to fewer, not greater, strikes. Lawyers and government officials sit in operations rooms looking at video feeds, vetoing any action that would not be considered legal. Moreover, unlike pilots at the scene of the action, remote control strikers are not caught up in the rush of combat, putting them at less risk for potentially making tragic decisions with imperfect information. In this vein, robotic warfare is sometimes presented as having moral advantages because they are not human. Robot soldiers will not carry out revenge attacks on civilians, commit rape, or panic in the heat of battle. They do not have human emotions like fear, anger, and guilt, which may lead to war crimes, and they are not constrained by desire for self-preservation.

More complicated just war considerations will arise as remote controlled platforms with a human in the loop give way to semi-autonomous and potentially fully autonomous robots. Both discrimination and proportionality pose problems for a machine. Advances in artificial intelligence are underway, but still it is questionable whether robots will ever have the ability to distinguish civilian objects from legitimate military targets.[20] At the same time, a proportionality determination equates to a judgment call and, although proponents believe that complex machine judgment will be possible at some point in the future, this is debatable given the contextual nature of decisions. As Singer puts it, "Common sense is not a simple thing."[21]

THE WAY OF THE FUTURE?

In the 1990s, official U.S. policy argued against autonomy in warfare. The Joint Chiefs of Staff stressed that technology was meant "to equip the man," and that the soldier should not be merely operating the equipment.[22] Along these lines, a 2012 Defense Science Board report ruled out fully autonomous machines, stating they would at most be operating "within programmed boundaries, 'self-governing'," and always "*supervised* by human operators at some level [emphasis in original]."[23] That same year, a Department of Defense (DoD) directive on autonomy in weapon systems established guidelines stating, "Human-supervised autonomous weapon systems [i.e. semi-autonomous systems] may be used to select and engage targets, with the exception of selecting humans as targets."[24] The directive does not address fully autonomous systems.

Advances in artificial intelligence are starting to push the full autonomy envelope. Apart from making a distinction between self-directed and self-deciding machines, in 2013 the Pentagon set out a research program that foresaw autonomous systems able to make decisions and react without human interaction.[25] Each of the U.S. armed services is developing, and in some cases fielding, platforms that can operate in a semi-autonomous fashion; so too are Russia, China, and even smaller powers like South Korea along the demilitarized zone. Advances in artificial intelligence are such that it may be technologically possible for fully autonomous systems to become reality in the not-too-distant future.

The current debate centers on advances in artificial intelligence and the progression from remote controlled to semi-autonomous to potentially autonomous platforms coupled with lethal means of responding. In many cases there are no neat dividing lines between whether a platform can be considered nonlethal or lethal; their tool sets can include both, and it is a matter of which is enabled for a particular mission. Nonetheless, when thinking about where to focus efforts it is helpful to make a conceptual distinction between lethal and nonlethal platforms, as much as the degree to which these platforms are autonomous.

The United States and its allies should embrace and pursue nonlethal platforms of all varieties—remotely controlled, semi-autonomous, and fully autonomous—for their military effectiveness when they are operating alone; for their enabling and risk-reducing role when deployed with humans; and for the increased options they provide to leaders when responding to a crisis that does not pose a threat to vital interests.

It is clear that there are many occasions when a nonlethal unmanned platform will do a better job than their manned counterpart can. The surveillance of territorial waters, for example, can be done on a sporadic basis with long-range patrol aircraft, but a militarily more effective approach would be a fleet of medium altitude UAVs. Factoring personnel numbers into the equation, it would be still better if this fleet operated semi-autonomously. Other examples can easily be found—such as demining and, some believe, aerial refueling—where a machine would be militarily more effective than a human would.

The vast majority of operations will continue to require a human. As a result, a second area of robotic interest should be those nonlethal robots—again, remotely controlled but ideally semi-autonomous—that provide a critical role in support of deployed forces, facilitating their movement, and reducing threats and risks. A range of platforms pertain to this category including: robots for supply trains; the well-known UAVs that provide soldiers with ISR information during operations; robotic ground vehicles that similarly provide situational awareness; and unmanned surface vessels for reconnaissance and to warn manned vessels of threats.

States that pursue nonlethal robotic capabilities by default will increase their options in responding to international situations that demand a response, but are not of vital enough concern to warrant a large-scale military deployment. Faced with civil strife in a war-torn nation, for example, a government will think twice about sending ground forces if the circumstance does not pose a direct threat to interests. Yet it could send drones to help aid agencies track refugees or assist local or indigenous forces on the ground. While natural disasters are one-off situations where drones are often deployed, it is conceivable that a fleet of semi-autonomous nonlethal drones could monitor on a sustained basis ongoing civil strife, such as in Sudan. Airborne platforms seem best suited as a humanitarian assistance and disaster relief contribution, but in the future, robots in the other dimensions of war may be similarly useful. It is possible, for example, that units dominated by nonlethal remote controlled or semi-autonomous ground vehicles could undertake the task of distributing humanitarian aid. In addition, one of the habitual problems of peacekeeping and stabilization missions is insufficient troop strength. Nonlethal robots could be used to augment boots on the ground in missions that require the presence of many troops over a long period of time.[26]

As for lethal platforms, remotely controlled robots with a human directly in the loop should be pursued in all dimensions of warfare to enhance military effectiveness and reduce risk to friendly forces. The challenge will be for militaries to integrate such platforms into new doctrines, rather than merely adding them into existing modes of operation. Military leaders will need to rethink existing force structure concurrently, taking into account remotely controlled lethal robots as an integral part of tomorrow's navies, armies, and air forces. Remotely controlled lethal warfare foresees both robot-on-human and robot-on-robot engagements. While the robot-on-human aspect is already with us (e.g., close air support of troops and striking terrorists), to date there have not been any remote controlled robot-on-robot engagements such as air-to-air battle between UCAVs. It is here that perhaps the most doctrinal work needs to be done.

Hard questions arise when we enter the realm of semi-autonomous and potentially autonomous robotic machines that are at the same time lethal. In any conflict, civilian and military leaders will want to undertake whatever measures are necessary to reduce the risk to their own warfighters. There will almost certainly be cases where fielding lethal systems that are not tethered to a human being would significantly reduce the risk to soldiers, sailors, or aviators. However, these systems are as yet unable to meet the discrimination and proportionality (judgment) requirements of the law of armed conflict, and such artificial intelligence may never be obtainable. Moreover, regardless of how smart a robot becomes, it is not clear whether it would ever be ethical for a machine to kill a human.

Most would agree that it is acceptable for a robot to "kill" another robot—machine-on-machine warfare that is already exhibited, for example, by semi-autonomous anti-ship missiles striking an incoming missile. Leaders will want to deploy semi-autonomous and autonomous kinetic systems only in closely prescribed scenarios where machines are likely only to encounter other machines. In practical terms, this may be more likely in the sea and air environments than on land. It will be tempting to deploy autonomous robots with soldiers on the ground to provide defensive cover since in principle this would reduce the risk to the soldier. Nevertheless, the challenges of artificial intelligence are such that a robot may not be able to distinguish between another robot and a human, since robots are becoming increasingly lifelike.

Lethal semi-autonomous (and certainly fully autonomous) robots would not be well suited to unconventional, irregular war involving nonstate actors, nor would they be suited to special forces operations. In these highly context-dependent situations, the lines between civilian and military are often blurred, and a premium is placed on the ability to make a distinction between combatants and noncombatants. The conduct of war in these circumstances should involve humans, augmented to as great a degree as possible with nonlethal platforms of all varieties (remote controlled, semi-autonomous and autonomous) and with lethal remote controlled systems.

CONCLUSION

Lethal autonomous robots, should they appear, will occupy a unique moral ground. On the one hand, they would be clearly different from all those kinetic systems in which the trigger decision can be traced to a human. On the other hand, they would not cause the type of superfluous suffering that is associated with chemical and biological weapons and that led to their ban, nor would they cause the massive and indiscriminate destruction of a nuclear weapon. Indeed, lethal robotic systems are more likely to be precise and cause limited collateral damage. Arguments for constraining the development and use of autonomous lethal robotic systems are grounded more in ethical than physical concerns, and as such, their acceptability will be conditioned by changes in the ethical environment. America's decades-long ethical prohibition on unrestricted submarine warfare was reversed within hours of the attack on Pearl Harbor. Policymakers will want to consider what would prompt a similarly dramatic change in perspective on autonomous lethal robots, and be ready to respond.

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CHAPTER 2. CURRENT AND EMERGING TECHNOLOGY IN MILITARY ROBOTICS

Simon Monckton

BACKGROUND

Robot, a Czech term for "worker," has many modern definitions, most implying some degree of programmability. In popular use, robot covers everything from tele-operated manipulator arms to software agents. While the term is a useful touchstone in the popular press, within the industries that use them, "robot" has been largely replaced by terms that are more specific.

Military robots have existed in one way or another for well over a hundred years. Some of the earliest examples include mines, torpedoes, and early guided munitions. Land and water mines have a long history. Some of the earliest known references are of buried 12th-century Chinese ground thunder (*ti lei*) mines.[1] More than simple burning fuse explosives, these buried mines had a rudimentary victim-triggered detonator (e.g., mechanically tripped flint/strike) often lighting a network of linked mines.

In response to Adriatic coastal raiders of the 1860s, a retired Austro-Hungarian naval officer, Giovanni Luppis, developed a crude shore-launched torpedo. In 1864 he enlisted Robert Whitehead (see figure 2-1), an English factory manager in Sarajevo, to improve the rope-guided prototype. He would go on to develop the first self-guided torpedo in 1866, and in the process, spawn practical submarine warfare.

Figure 2-1. Robert Whitehead (right) and Son John (left) with the Fiume Test Torpedo.[2]

More ambitious systems arose in the 20th century, notably the Kettering Bug, an early attempt at a guided aircraft munition (1918); the *Vergeltungswaffen*-1 (retribution weapon), also known as the V-1 "Buzzbomb" (1943); the V-2 ballistic missile (1944); and obscure, but important systems such as the Fritz X and the HS-293, German radio guided air-dropped gliding munitions (1943). (See figures 2-2 through 2-5.) All of these systems demonstrate the rapid evolution of inertial navigation systems (INS) that used pendulums, balances, or gyroscopes for vehicle control. Coupled with altitude (or depth) pressure sensors and internal timers, these vehicles could follow an altitude-attitude-time "program." As the first faltering steps in robot navigation, none of these systems were very accurate (e.g., the V2 had an appalling circular error probable [CEP] of 17 kilometers from 500 kilometers away).[3] Indeed, radio control was often considered to improve accuracy (e.g., a CEP of 26 meters for the radio-controlled Fritz-X) at the risk of operator proximity (a few kilometers).[4]

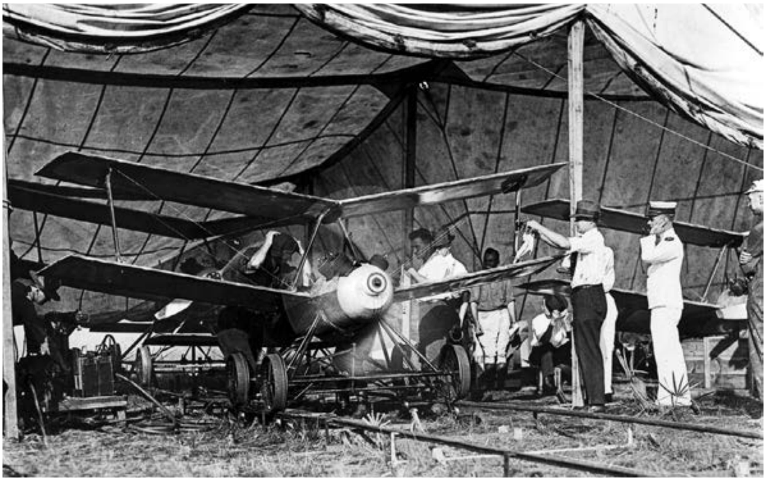

Figure 2-2. The Kettering Bug.[5]

Figure 2-3. The V-1.[6]

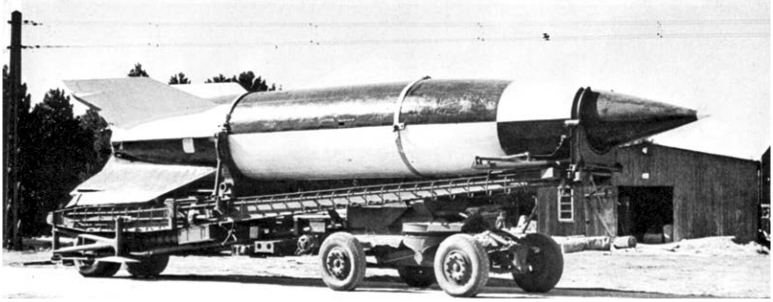

Figure 2-4. The V-2.[7]

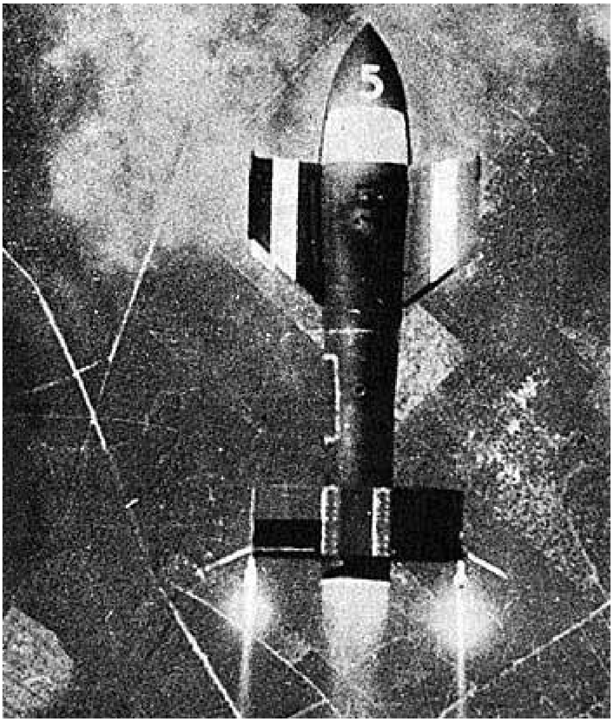

Figure 2-5. The Fritz-X.[8]

In the last 2 decades, this trend has gained momentum with unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), unmanned underwater vehicles (UUVs), and unmanned surface vehicles (USVs) becoming an increasingly common military tool. Why is this so, and what is the future for these novel machines?

RATIONALE FOR MILITARY ROBOTICS

The popular press commonly invokes the dull, dirty, and dangerous catchphrase as the rationale for robot adoption. However, this clever alliteration boils down to two crucial features:

1. **Standoff**—we want to keep humans out of harm's way; and,
2. **Precision**—we want reliable and precise operation.

Dull references human patience or, more specifically, how operators can express boredom through inattention and increased error. Humans dislike dirty and dangerous tasks that can make for hasty execution and further error. Standoff captures the key capability of using machines in place of a human for these tasks. Precision captures the programmability of these machines and their consistent, often superior, performance—albeit with human oversight.

This chapter will briefly discuss the technical problem engineers seek to solve in fulfilling these objectives with military robotics. Using some examples, the paper will try to provide a basic understanding of where the technology is today and where the technology might be going.

COMPLEXITY

With this kind of history and rationale, why do we not have "robot soldiers"? The simple answer is that battlefield missions, environments, and systems present profound complexity to robot development; so much so that relatively simple robot systems (e.g., industrial robots and UAVs) are confined to highly regimented tasks (e.g., path following) in only the simplest of environments (factory floors and open air).

An increase in any of the three primary types of complexity (mechanical complexity, environmental complexity, and mission or task complexity) radically increases the required capabilities of a robot. Figure 2-6 depicts this as a crude coordinate system similar to the National Institute of Standards and Technology's (NISTs) Autonomy Levels for Unmanned Systems (ALFUS) framework.[9]

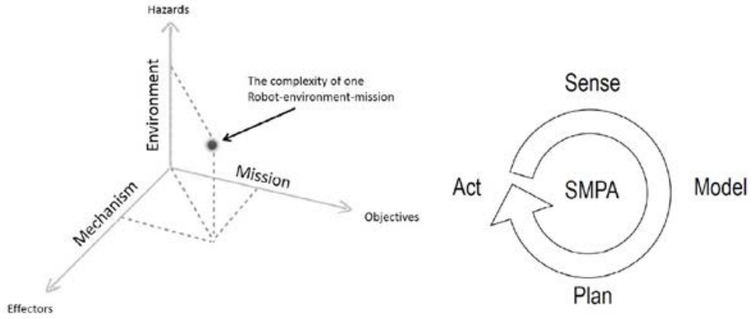

Figure 2-6. Complexity (left) Can Be Expressed as a Set of Three Loosely Related Coordinates: Mission, Mechanism, and Environment. Using a Sense-Model-Plan-Act (SMPA) Cycle (right), a Robot Must Sense and Model the Environment, Plan the Mission, and Act Through the Mechanism.

When a robot meets or exceeds these complexity requirements, the system is often labeled autonomous. In other words, autonomy is a subjective assessment of a robot's capabilities given the demands of mission, environment, and mechanical system. The less help the system needs, the more autonomous it seems.

To reduce the need for human help requires a machine that senses the environment to build a useful model; then it plans a mission and uses its mechanism to act on the world. Rodney Brooks, the founder of iRobot, described this as the SMPA cycle as depicted in figure 2-6.[10] A robot must have sensing, modeling, and planning capable of expressing the environment, mechanism, and mission as it changes over time—a notion that dates back to the earliest days of artificial intelligence.[11]

Over the last century, sensors have grown from simple switches, angle, displacement, and pressure sensing to include hyper-spectral imagery, sonar, and light detection and ranging (lidar), to name a few. They have evolved from returning single values to multi-dimensional data sets. For all this, extracting meaning from this data stream remains a central problem shared by sensing and modeling, making most robot sensors and models a crude approximation of the human experience.

While we know modeling and planning are important, how this should be done remains unclear and constitutes a large area of investigation. Of course models can contain much more data than merely position (e.g., communication strength, soil conditions, turbulence), making for one or more very high dimensional structures. The modeling process interprets, categorizes, and stores this data using the most accessible, compact methods. For example, this could mean lidar three-dimensional (3D) range data becomes a point cloud database or, perhaps, a simplified voxel (volume pixel) world akin to Minecraft™—all dependent on the system's planning needs. Engineers invariably match sensors with models, either by crafting models specifically for some sensor types or throwing out sensor data that the model does not need. Ultimately, though, the models must integrate, analyze, and store multiple sensor readings at varied data rates into a single model. Yet, this model must also be responsive to the planning cycle—often looping at an entirely different rate. Perhaps more than any other system, the model is caught between a hammer of efficiency and the anvil of speed.

However, some control techniques can lessen this burden, such as reactive control and passive mechanics. Indeed, some systems can get by with virtually no model or plan at all, such as iRobot's Roomba,™ by using reactive rules triggered by simple sensors. In a sense, the model and plan are frozen into hardwired circuitry at design-time. During the 1990s, these architectures showed great promise, but have since been found difficult to scale to problems that are more complex. Alternatively, some computational complexity can be absorbed through insightful mechanical design. For example, suspension linkages and tracks can reduce the need for detailed world models by smoothing rough terrain. Similarly, model accuracy can be reduced if compliant joints can make up for imperfect tool alignment.

Nevertheless, to guarantee a predictable outcome, SMPA still needs a model of the problem and some kind of planning process known as a deliberative system.

Some planning problems are amenable to exact or analytical solutions, but most real world problems are not. Planning systems often search through multiple solutions, testing one after another. This might be as basic as finding a route over difficult terrain or as complex as planning an airborne mission to observe multiple enemy sites, gliding to conserve fuel, while maintaining line-of-sight communications over mountainous terrain in variable weather. The bigger the planning space, the more time consuming finding a satisfactory—let alone optimal—solution becomes. In practice, most use a blend of simple reactive rules-of-thumb, analytical methods, and search techniques to get reasonable performance in reasonable time.

With a model and plan, a robot can act, which often means driving or flying a vehicle or tool along some path composed of physical positions but possibly other abstract states (e.g., engine revolutions per minute [rpm], payload pointing angle, etc.) at the same time.

As described, the SMPA process seems simple enough. Unfortunately, real world environments and missions make robot systems design a very difficult engineering problem, and the SMPA approach becomes very brittle. As environmental complexity grows, so too does the volume and complexity of required sensing (as in figure 2-7). Models must grow to cope with this flood of sensor data. The mission and mechanical system, too, may add to complexity, requiring additional sensing and modeling. For example, a mission might require a robot to "go to forward operating base Alpha"; "listen for friendly forces"; "avoid enemy sensing"; or "conserve fuel." As the model grows, the planning space grows and, with finite computing resources, the planning time lengthens.

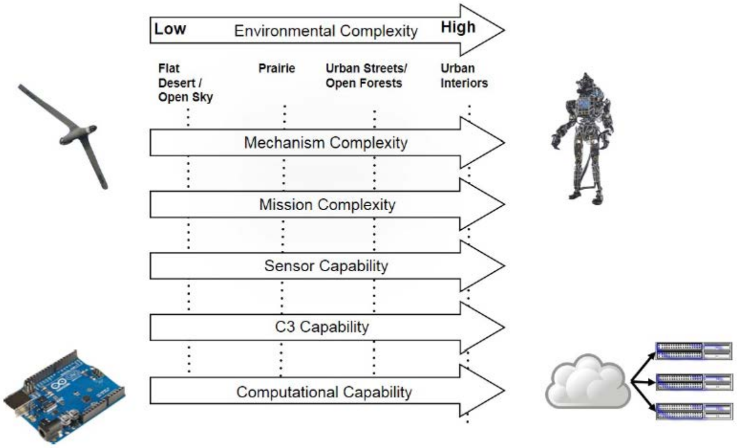

Figure 2-7. Growing Environmental, Mechanical, or Mission Complexity Only Increases the Sensing, C3, and Computing Capability Needs from Simple Systems (left) to Complex Systems (right).

To simplify the problem, some systems use parallel SMPA systems to generate simultaneous "behaviors." An action may then involve a compromise between actions, simultaneous actions, or action chains. Interestingly, interactions between behavior systems can produce emergent behavior (e.g., Brooks' walking robots).[12]

The demand for greater memory, computing power, and mobility as the environment and mission become more complex makes the future of robotics sound pretty bleak. However, the last decade has seen some significant technological changes, some widely known, and others known only to robotics practitioners.

CURRENT STATE OF THE ART

Some key technologies support modern military robotics and also remain an important assumption for research robotics:

1. Electronic miniaturization;
2. Telecommunications; and,
3. Global Positioning.

The first driver is electronics. Most have heard of Moore's Law, the idea that transistor density (and therefore computing power) doubles every 2 years (see figure 2-8). Though microprocessors underpin virtually every robot subsystem, micro-electro mechanical (MEM) accelerometers and gyros made with the same production process provide cheap, accurate, and incredibly small INS when combined with global positioning. MEM-based sensors have revolutionized embedded controllers, making robots, notably quadrotor UAVs, small, simple to control, and inexpensive. Indeed, robot sensing has undergone a revolution in the last decade as image sensors, lidar, radio detection and ranging (radar), and stereo imagers have collapsed in size and cost.

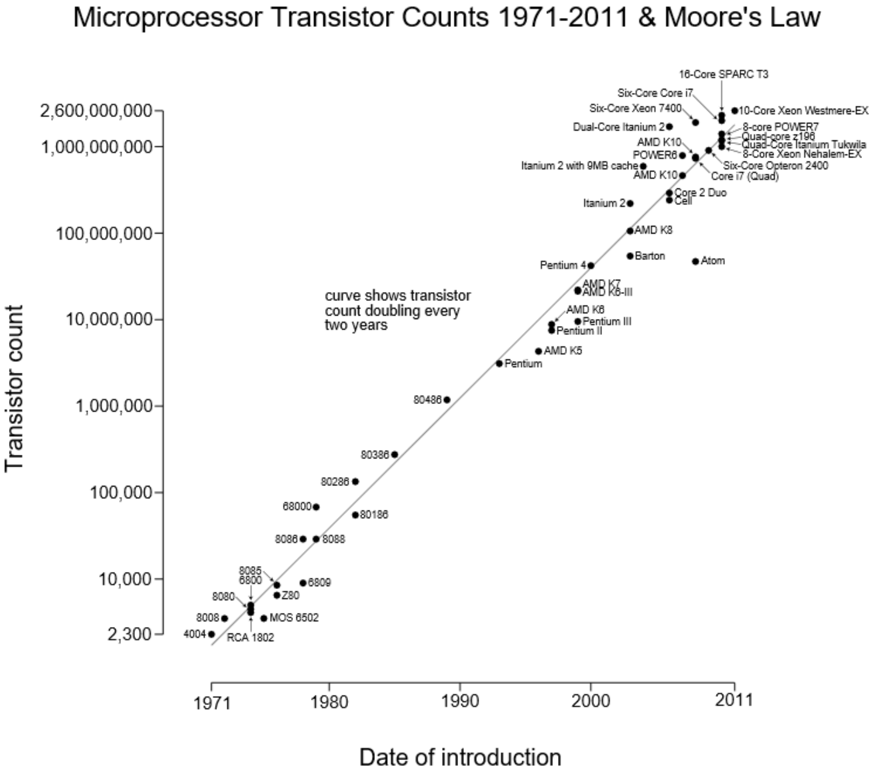

Figure 2-8. Transistor Count and Moore's Law—2011.[13]

Miniaturization has greatly changed telecommunications and—since current robots have only the most basic situational awareness—this makes communications to a human operator essential. Indeed, military and civilian robots rarely, if ever, go "off-leash," without any operator control. Industry provides a wide variety of options: from line-of-sight systems such as long range (100 kilometers or less)/low bandwidth (100 kilobytes per second or less) frequency hopping spread spectrum wireless modems and short range(1 kilometer or less)/high bandwidth Wi-Fi and cell networks (50 megabytes per second or more), to beyond-line-of-sight low bandwidth Iridium™ (2.4 kilobytes per second or less) and dedicated high bandwidth Satellite Communications (SATCOM) (10 megabytes per second or more).[14]

Finally, virtually all robots require access to a Global Positioning System (GPS), such as the U.S. GPS or Russian Global Navigation Satellite System (GLONASS) networks, that transmit precise timing signals every second. A receiver can use small timing differences from different satellites to compute the receiver's position and altitude. In combination with other sensors, GPS provides a precise global coordinate and time synchronization system in which models and plans can be built and executed. That said, current models and plans are rarely more than a map and a set of waypoints, as shown in figure 2-9.

alt 87.35
groundspeed 15.38
wp_dist 49

37.9526863 -122.013405 86.89 Zoom 17.0

Figure 2-9. A Modern Autopilot Control, an Ardupilot Ground Control Station.[15]

Single-handedly, GPS has made the prospect of military robots at least conceivable for a wide range of low complexity applications.

Miniaturization, GPS, and telecommunications combine to give remote operators the precise location and internal state of modern robots. Yet beyond GPS and INS, most robots provide operators with little awareness of the outside world; neither UAV nor operator can yet see other air traffic and must fly in segregated airspace, and UGVs are helpless without direct human control.

So while we can build mechanically complex robots that land on carriers, trot through forests, climb walls, and navigate parking lots, their actual capacity to sense, model, and plan for these environments is primitive and relies completely on INS, communications, and human operators. Emerging technologies may make these systems more reliable.

EMERGING TECHNOLOGIES

A number of new drivers promise great change:

1. Probabilistic robotics;
2. Networking; and,
3. Parallel processing.

Probabilistic robotics—an obscure subject to the uninitiated—has completely changed the face of robotics over the last decade.[16] As mentioned earlier, the SMPA cycle can be brittle. One small error in sense can grow into broken machinery at the end of the act. Probabilistic robotics encompasses techniques that can incorporate imperfect sensors into models, plans, or actions, and takes uncertainty into account at every step of SMPA, ensuring that the outcome of the plan achieves the best result.

Some good examples are in machine vision. By combining probabilistic feature tracking with novel image processing, new vision algorithms can simultaneously sense position and build models—a process known as simultaneous localization and mapping (SLAM). This will lead to human-like sensing systems that can passively locate and model the world simultaneously, such as University of Pennsylvania, General Robotics, Automation, Sensing, and Perception (GRASP) lab's indoor mapping work.[17]

The Network, specifically the Internet, is an important robotics technology for numerous reasons. Since the late 1970s, networking has rapidly grown into every facet of modern life to become the Internet "cloud." However, network protocols have not yet penetrated robot communications—military robot systems are not yet interoperable like most computing equipment. Nevertheless, robotics benefits from the Internet, to include in some unexpected ways:

1. While robotics research has always built on the algorithms of others, academic investigators routinely publish the actual code for these algorithms to the Internet. This simple act permits vigorous verification, validation, maintenance, and extension by the online open source community. The Robotic Operating System (ROS) is an excellent example of the Internet's impact on technology development, dissemination, and standards in software and robotics.[18]
2. Network Communication means robots can share sensing, modeling, and planning between robots.

3. Computing need not be resident in devices, indeed robots need not carry their own computing horsepower at all. Though often mistakenly cited as an example of advanced UAV embedded control, the GRASP lab's quadrotor program provides an excellent example of offloaded UAV control.[19]

To be useful, network communications on the battlefield must be fast, reliable, and interoperable. New standards promise interesting capabilities such as decentralized SMPA, where sensing, modeling, planning, and action could be distributed over multiple robots scattered over the battlefield.[20]

To some degree, networking has helped drive parallel processing. To meet Moore's Law over the last decade, the semiconductor industry has been forced to develop parallel central processing unit (CPU) architectures. From multicore CPUs on most desktops to array graphics processors on gaming consoles, parallel architectures permit simultaneous processing that speeds numerically intensive tasks such as game rendering (a form of modeling), multi-bot melee and search (planning), audio- and gesture-based interfaces (sensing)—all of which benefit future robotics. SLAM in particular and probabilistic methods in general will be key beneficiaries of parallel processing architectures.

THE FUTURE OF ROBOTICS

For the foreseeable future, unmanned underwater, surface, and air vehicles (UxVs) will slowly enter more complex environments as sensing, modeling, and planning improves, meaning that:

- UAVs will descend into lower altitudes and penetrate more complex airspace as parallel

processing and high speed local networks provide fast sensor processing, shared models, and faster planning for dynamic flight amongst structures. Examples include shipboard operations, urban 3D mapping, and organic convoy route clearance.[21]
- UUVs will penetrate closer to shore near vessels and harbor facilities as parallel processing permits faster on-board sonar imaging for roles such as harbor or hull inspection and waterway demining.
- UGVs will need less handholding to perform complex operations, supported by powerful onboard parallel computing, long-range networking, and high mobility platforms.
- Air-ground cooperation seems likely with overhead UAVs providing top-down mapping capabilities and communications relay for ground vehicles. Examples here are more difficult, but will likely include squad support robots, indoor intelligence, surveillance, and reconnaissance (ISR) robots, and smart convoy vehicles.
- Marsupial robots, or robots carrying robots, are a significant possibility, particularly UAV-delivered UGVs or UUVs, and UGV-delivered UAVs. This tactic allows a system to operate at multiple scales, for example, a high altitude, long-endurance, fixed-wing UAV could deliver smaller micro UAVs to provide both high altitude ISR and in-building mapping.

These machines will likely be designed from the start as network devices, with considerable parallel processing on-board, and will naturally cope with uncertainty in sensing, planning, and modeling.

Do these promising technologies provide the means for robots to operate on the battlefield without human control? In the author's opinion, a tactically useful and legally permissible system will not be technically feasible for the foreseeable future other than through substantial off-board computing and high bandwidth communications. In which case, these machines are essentially tele-operated—which raises an interesting question to follow about the evolution of military robots.

The Cameron Dilemma—consider the following engineering problem:

> With 5 years and unlimited resources, you must produce an unmanned combat system equivalent to a human combatant. Which of the two design strategies would you invest in?
>
> 1. A Remote Tele-combat System: A system that permits human soldiers to operate a remote combat robot as though they were there in person (e.g., Avatar).[22]
> 2. An Autonomous Combat System: A system that permits robots to autonomously sense and act in the world identical to a law-abiding human combatant (e.g., Terminator).[23]

Most instinctively answer with the Avatar strategy, revealing an understandable doubt about the structure and nature of intelligence and respect for the complexity of combat. The answer also acknowledges that human operators have immense natural capabilities even when confined to tele-operation.

From the purely technical perspective, every innovation that supports the Terminator strategy benefits the Avatar strategy primarily. Since there are many reasons why a pure Avatar strategy might fail on the battlefield (communications jamming, time delay, impoverished sensing, and human comprehension limits to name a few), a mixture of these two methods seems the most likely outcome. In any case, the result will continue to support human oversight in the service in the same basic principles of standoff and precision.

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CHAPTER 3. ROBOTICS AND MILITARY OPERATIONS: POLICY IMPLICATIONS

Tony Battista

While predictions in military affairs have always proven challenging, one can identify emerging trends in the use of autonomous systems by the military that are worthy of serious consideration by the scientific community, military planners and practitioners, scholars, legal experts, and policymakers alike. This chapter is largely for the purpose of discerning policy implications for the use of autonomous systems in future conflict and military operations.

One thing is relatively certain: geopolitics, technology, and war remain inseparable. Technology, geopolitics' companion, has evolved dramatically: nuclear weapons, satellites, Global Positioning System (GPS), precision-guided weapons systems, the microchip and nanotechnology, artificial intelligence and robotics, and huge advances in communication technology, including social media—among other wonders and horrors—have changed not only the rules of war but also the circumstances under which war is possible and to what end! Arguably, more than ever, there is an increasing trend to blur the distinctions between criminal and terrorist acts, and war. We now live in a high-tech versus a low-tech world, often confronted by the dark-age mentality of parasites and chameleons who have no recognizable standards to constrain their violent actions, whether legal, moral, or ethical. Some nonstate groups—and even self-proclaimed states—make no compunction about dying for their cause; in fact, they plan on dying! So how does one rationalize this phenomenon, especially in light of developments in autonomous armed systems?

The current and future security environment, increasingly defined by asymmetric and unpredictable threats, international laws, and norms—both new and revised—must grapple with emerging challenges in order to prevent or minimize the loss of life, either by human hands or by machine. It is clear that nonstate enemy combatants are unlikely to act in accordance with international laws regarding the use of autonomous systems. We should also question whether certain states would even comply. Exploiting the ambiguities of these emerging autonomous (and disruptive) technologies by providing an edge to a belligerent would make compliance with international norms and regimes even more profoundly complex, not less.

Notwithstanding these enormous challenges, the 2015 Kingston Conference on International Security (KCIS) participants rightly acknowledged the need to further the understanding of the legal, ethical, and strategic implications of autonomous and semi-autonomous systems. Robotics is still in a pioneer stage and, as such, we have much to learn and to discover about their full potential, implications, and lethality. Moreover, learn we must, as the advances are accelerating at an impressive pace. Nuclear weapons were considered unthinkable for future use after Hiroshima and Nagasaki, yet their development continued thereafter at an alarming pace. Unlike the post-nuclear age, however, there is currently no comparable robotic stigma, and the international community has yet to define what even constitutes an autonomous system. Hence, the argument can be made that the policy implications and the development of a credible (and enforceable) control regime will remain elusive for quite some time.

Controversy abounds when trying to demarcate autonomous systems and, more broadly, robots. For instance, in the United States, there are attempts to define robotic systems by making distinctions between the execution and performance of a machine. Alternatively, some academics base their definitions on a more technical level and argue that a robot is composed of sensors, processors, and tools. The lack of consensus on an internationally accepted definition has hindered the development of laws governing these systems. Several scholars at the conference maintained that in order to make a legal assessment of these systems, one needs to examine a particular weapon in a particular context.

Moreover, a number of attendees at the conference took issue with the Human Rights Watch campaign to prohibit the rise of "killer robots." Human Rights Watch contends that these:

> 'killer robots,' would be able to select and engage targets without human intervention. Precursors to these weapons, such as armed drones, are being developed and deployed by nations including China, Israel, South Korea, Russia, the United Kingdom, and the United States. It is questionable that fully autonomous weapons would be capable of meeting international humanitarian law standards, including the rules of distinction, proportionality, and military necessity, while they would threaten the fundamental right to life and principle of human dignity.[1]

For these reasons, Human Rights Watch has called for "a preemptive ban on the development, production, and use of fully autonomous weapons."[2] The counter-argument asserts that an arms control approach is not meaningful and is, in fact, counterproductive. Rather than preventing their development, greater efforts should be made to ensure that the use of robotic systems complies with the Law of Armed Conflict. Arguably, a massive point of legal contention revolves around the reliability of these systems; we fear a science fiction based scenario where robotic systems surpass our own intelligence, or we fear that autonomous systems are not intelligent enough to be reliable when paired with lethal ordnances.

This possibility underlines the threat potential of autonomous systems to the global community at large. Even if autonomous systems are intended for use by allies to undertake surveillance activities or as a force multiplier, potential users of these systems (both friend and foe) will always find unforeseen applications for these devices. To assess thoroughly the threat potential of these devices, as well as how the Canadian Armed Forces (CAF) and its allies and partners should respond, one must consider all the possible ways these systems might be used, rather than simply focus on how we use them now or the manner in which they were intended to be used.

With rapid technological growth come challenges, such as defining robotics and their legal applications in combat. However, this rapid growth also creates opportunities. We should view these opportunities as both an evolution and a potential revolution in the security environment. Robotics is unlikely to replace all aspects of human control and oversight in combat. Yet, it gives us the capabilities we need to wage a smarter form of warfare, including the promise of reducing the risk to our soldiers. Ultimately, technology will advance, and war will persist, as we continue to face determined enemies and threats that we have yet to appreciate.

Consider the following from a policy implication perspective:

1. The trend for further development of quasi- or fully-autonomous systems for military purposes will continue, and the use of these systems is virtually inevitable. We should think on how to deal with its implications, rather than stick our heads in the sand and pretend that it will not happen, or focus all of our energy to prevent their development in the first place.
2. Policymakers are generally not well prepared for tough decisions with long-term, strategic implications. This is even more so in democratic states, which usually have 4- or 5-year cyclical horizons. As such, more efforts need to be made to prepare decision makers to think and act on longer-term horizons.
3. To paraphrase George Friedman, war is an old dance now being accompanied by new musical instruments. We must stay in-step with these new musical instruments; otherwise, we may not only find ourselves off the dance floor but under it!
4. For Canada and like-minded allies, there is a need to strengthen the focus on collaboration on innovation, and interoperability and integration (CI2I)—(or see eye-to-eye)—regarding new and emerging autonomous systems. The focus has to be broadened beyond the existing American, British, Canadian, Australian, and New Zealand Armies' Program, which is focused on the interoperability issue of autonomous systems. This approach would give Canada a better chance to stay abreast of new technological breakthroughs, mitigate the possibility of adversaries developing and using robotics against us, and provide for a better

understanding of the implications of autonomous systems. A new international, inter-disciplinary Manhattan Project for autonomous systems could be a visionary step that would give like-minded states an edge in the development of autonomous systems and mitigate the use of these same systems against them by unscrupulous groups and rogue states.

5. There is a need to invest in effective wargaming with autonomous systems, including broadening our understanding of the implications for command and control (C2). These systems are already being used—in various degrees and sophistication—at the tactical level in many military operations around the world. If "killer robots" were given the ability to select and engage targets without human intervention, what are the implications for C2 nodes at the various levels of military operations (tactical, operational, strategic/grand strategic, and political)? Perhaps the most complex of implications is the danger of "moral de-skilling" of the human military professional at all levels, and replacing the human at crucial decision making nodes that have broad implications in the conduct of military operations (as a means to an end). According to a recent article by Megan Spurrell, fully autonomous weapons are capable of detecting and executing targets without human intervention. The technology remains in experiential development, but experts warn that it will not take long to transform the next generation of unmanned aerial vehicles (UAVs) into "killer robots." The Bureau of Investigative Journalism estimates that all that is needed is an

algorithm to fire missiles on a drone's own recognized targets, and we are not far from reaching this stage.[3]

6. While robotics is no silver bullet for either deterring war or waging it successfully, mitigating surprise by a ruthless adversary is essential. While it matters if someday we are able to advance technology to a state whereby autonomous systems are able to completely replace and supplant humans, it is even more important to understand how a determined adversary might use technological advancements to wage war, including the unpleasant possibility of humans becoming robots themselves! Ultimately—and despite the very unconstrained actions of some barbaric groups—we should continue our efforts to ensure that the purpose of waging and managing organized violence should remain a tool of last resort. It is one thing for machines to kill each other; it is another for machines to decide how, when, and why to kill human beings.

In conclusion, Canada and its close allies are urged not only to maintain a close eye on emerging technological trends, but also to participate in the development of these technologies and understand the impact of their use, while continuing to embrace the Laws of Armed Conflict. War may not be the best way of solving differences, but it does ensure that differences are not settled for us. We should not limit the pursuit of technology that would allow us to defend ourselves and to settle those differences—in our interest—with fewer losses.

ENDNOTES - CHAPTER 3

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