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Preventive Arms Control for Uninhabited Military Vehicles

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Abstract. Increasingly armed forces use vehicles without crew on board, mostly for reconnaissance. However, some uninhabited aircraft are armed already. Decisions on what or whom to attack are made by far-away operators watching images from video cameras on the vehicles. But there is a trend to move from remote control by a human to autonomous killing decisions. When uninhabited vehicles are assessed under criteria of preventive arms control, they give reason for concern in several areas. Dangers can arise for arms-control treaties and the international law of warfare. The situation between potential opponents can become more instable, arms races and proliferation can be foreseen. Small systems could be used for crimes including terrorist attacks. To avoid such dangers, preventive limitations should be negotiated internationally. Optimally these will include a complete ban of armed uninhabited systems; at least, attack decisions by machine, without a human in the loop, should be prohibited.

Keywords. Arms control, arms race, disarmament, peace, proliferation, stability, technology assessment, uninhabited/unmanned vehicle, verification, war, weapon

Introduction

Military uses of technology are quite different from civilian ones. In the latter, many efforts are spent to prevent damage and destruction, so these occur only rarely, mainly by accident. Intentional misuse is limited to a few criminals. Military technology, on the other hand, is intentionally designed to effect (or support) organised destruction, to apply violent force more effectively in order to break the will of an opponent. In recent years, the military push for new technology has increasingly incorporated vehicles without crew, mainly as so-called uninhabited (or unmanned) aerial vehicles (UAVs). These are produced and developed by more than 50 countries (Jane's, 2007); mostly they are used for reconnaissance and surveillance, but first models have been armed, and US forces now routinely attack targets in Iraq, Afghanistan and Pakistan by missiles fired from UAVs (Weber, this volume). Much of the flight control is done by on-board processing, but general directions and in particular attack decisions are given by remote control, often via satellite link from hundreds to many thousands of kilometres away. For the future, however, autonomous machine decision about what or

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whom to attack is envisaged.[2] Obviously, killing of humans by autonomous technical systems raises fundamental ethical questions.[3] But there may be more problems, as discussed below.

Also in development are uninhabited vehicles for movement on land, on and under water, and in outer space. The combination of vehicles and the associated control systems, communication links, launch gear and other infrastructure is now denoted as unmanned systems (UMS). In one or two decades, enabled by microsystems technology and nanotechnology, some of these vehicles may be small (centimetres) or very small (down to millimetres or even below) (Altmann, 2001, 2006).

Superficially seen military systems without people on board seem attractive – they can carry out dull, dirty or dangerous tasks better than human soldiers or save lives of one's own soldiers. But exactly the latter prospect may induce states to start wars more easily, in particular (industrialised) democracies where too many casualties on one's own side may endanger support for a war (Müller, 2004). Beside this general political problem, there are more direct consequences: armed uninhabited systems can destabilise the military situation between potential opponents; some could proliferate and be used by terrorists.

This contribution discusses the latter problems. After a few remarks on nomenclature, preventive arms control is presented as a general framework for assessing new military technology and then applied to the problem at hand. Next, preliminary recommendations are given, followed by conclusions.

1. Nomenclature

Various names have been used for uninhabited vehicles in particular for aircraft, such as "remotely piloted vehicle" or "drone". The notion of "robots" is somewhat vague, encompassing on the one hand immobile industrial robots, on the other hand it is loosely associated with movement on land, often with walking with legs. Recently, the US military has systematised its categories, speaking of "unmanned ground/surface/ underwater/air vehicles" or the respective "systems", with the acronyms UGV/S, USV/S, UUV/S, respectively, plus the general UMS. However, the US Department of Defense by way of decree excludes certain systems from its definition of UMS, namely "ballistic or semi-ballistic vehicles, cruise missiles, artillery projectiles, torpedoes, mines, satellites, and unattended sensors" (Department of Defense, 2007, p. 1). This is only convincing in the case of immobile objects such as mines and unattended sensors, and in case of artillery grenades which travel purely ballistically without their own trajectory control. Cruise missiles and torpedoes, however, share many properties with existing or foreseen UAVs and UUVs, respectively, and the overlap will only become

[2] "Initial applications of weaponizing any unmanned systems may require a 'man in the loop' (e. g., MQ-1B Predator, MQ-1C Sky Warrior, and MQ-5 Hunter UASs) to ensure positive control of the vehicle and its weapon." (Department of Defense, 2007, p. 54). The Army Research Office and the Office of Naval Research in the USA are sponsoring research on ethics of autonomous lethal robots (Arkin & Moshkina, 2007; Arkin, 2007; Moshkina & Arkin, 2008; Lin et al., this volume).

[3] One military writer called this prospect "frightening" (Metz, 2000). See also Sharkey, 2007, 2008, 2008a, 2008b, and the list of issues given by Lin et al. (this volume). Note that the US Department of Defense states: "Weaponizing unmanned systems is a highly controversial issue that will require a patient 'crawl-walk-run' approach as each application's reliability and performance is proved." (Department of Defense, 2007, p. 54).

bigger over time. The motion of ballistic missiles is controlled at least in the boost phase, and satellites – most of them traditionally without crew on board – have to correct their orbit from time to time. So in a general definition one should include all types of vehicles the trajectory of which can be controlled during motion and which do not carry a human operator. There are or will be newer types with expanded capabilities, such as pilotless aircraft taking off and landing on runways whereas cruise missiles use special launchers and self-destroy on the target, or satellites for docking and manipulation of other satellites most of which are only capable of correcting their orbit. Such types might be captured by using "newer" or "in a narrow sense". Because "unmanned" is not gender-neutral, I use the notion "uninhabited" vehicle here.[4]

2. Preventive Arms Control

The history of technological arms races, in particular the Cold War, shows many examples where after one side had introduced a military innovation, potential opponents followed suit after only a few years. In many such cases, the mutual threat had increased, warning and reaction times had decreased, and stability was reduced. In those few cases where such developments could be reversed, it took many years for negotiations to begin and many more to come to a treaty. E. g., multiple independently targetable reentry vehicles (MIRVs) on long-range ballistic missiles were introduced in the early 1970s, despite expert warnings that they would be destabilising – they opened the principal possibility to destroy many more missiles of an opponent on the ground than the number expended in a first strike, so that the attacker's remaining high number might deter a retaliation with the few missiles left. To prevent such a situation, one can launch one's nuclear missiles on warning, before the attacker's missiles arrive, that is within 10-30 minutes. This "hair-trigger alert" introduces the potential for erroneous launch, and several nuclear crises show how close USA and USSR/Russia have come to nuclear war due to warning or computer errors. Only in the second Strategic Arms Reduction Treaty (START II) could the USA and the USSR in 1993 finally agree on de-MIRVing their land-based long-range ballistic missiles.[5]

The international system was and is characterised by the so-called security dilemma: lacking an overarching power which guarantees the security of states, each state tries – by self-help – to provide for its own security by building up armed forces. By so doing it increases the threat to others which in turn strengthen their armed forces for their own security. The net result is that the security is decreased for all. One way out of the security dilemma is mutual agreed limitation of armaments and forces, that is, arms control.[6] Whereas the "usual" arms control limits quantities or qualities of armaments that have already been acquired, preventive arms control acts at the preceding stages – it prohibits or regulates new, militarily usable technologies, substances or military systems which have not yet been introduced. Often the

[4] Thus the acronyms UAV (air), UGV (ground), USV (water surface), UUV (underwater) can be kept. The use of "uninhabited" instead of "unmanned" has some tradition with the US military already.

[5] This positive development is in danger now, however, because START II was replaced in 2002 by the Moscow Strategic Offensive Reductions Treaty, valid only to 2012, and re-MIRVing is one means how Russia could counter the perceived threat to their retaliatory force from US ballistic-missile defence systems to be deployed in Poland and the Czech Republic (Altmann & Neuneck, 2007).

[6] Texts of arms-control treaties and of export-control agreements can be found e. g. at http://www.armscontrol.de/, "Dokumente".

regulation concerns the stages of development and testing, research is sometimes involved indirectly. Where appropriate, civilian uses are regulated, too (Altmann, 2006, 2008, Ch. 5).

Even though preventive arms control was not a high priority during the Cold War, several agreements contain elements of it. The nuclear testing treaties (partial ban 1963, not including underground tests, and comprehensive ban 1996) ban explosive tests of new nuclear weapons and exclude research with live nuclear explosions. The Antiballistic Missile Treaty of 1972 (abrogated by the USA 2002) prohibited not only deployment, but already development and tests of anti-ballistic missile systems "which are sea-based, air-based, space-based or mobile land-based" (Art. V), all of which did not exist at the time.

The prohibitions of the Biological Weapons Convention of 1972 as well as the Chemical Weapons Convention of 1993 include the stages of development and production of the respective weapons. In the international law of warfare, the Protocol on Blinding Laser Weapons (1995) prohibits only the use of laser weapons designed to produce permanent blindness, but did so before such weapons were deployed, and has led to a stop of the respective research, development and testing in the relevant countries.

One might think that with the end of the Cold War and the dissolution of the Soviet Union many reasons for fast military-technological innovation have vanished, but the reality is different. After some decrease of funding for military R&D in the early 1990s, global expenses have risen again, from $ 69 billion in 1996 and 2000 to $ 85 billion in 2004,[7] with the USA clearly in the lead: about two thirds of the global expenditure for military R&D is spent by the USA (Brzoska, 2006). The USA traditionally has the explicit goal of technological superiority over all potential military opponents. After the attacks of September 2001, this goal has only been reinforced. Uninhabited vehicles/systems are seen as a central component in the so-called "global war on terror" and in the future force structure (Department of Defense, 2007, p. 6).

However, putting one's hope in national military strength will likely lead to the same problems today as experienced in the Cold War. At present, more than 50 countries develop or produce UAVs. Armed UAVs are possessed by the USA (Predator, Sky Warrior, Hunter, Reaper), Israel (Harpy, CUTLASS), Iran (Ababil-T). Uninhabited combat air vehicles (UCAVs) proper, that is for missions beyond attack of close-range land targets, are in development in the USA (UCAS-D); Great Britain (Corax), France (nEuron, with partner countries), Germany (Barracuda), and Russia (Skat) (Jane's, 2007). One need not be a prophet to predict that other producers of military aircraft and UAVs, e.g. China, India, Pakistan, Brazil, will put weapons on UAVs or develop full-blown UCAVs, also for export. Of course, such systems could also be used by other parties, including terrorists. E. g., Gormley (2003) and Jackson et al. (2008) have pointed out the possibility of cruise missile attacks on the US homeland or on US forces deployed overseas, maybe using modified anti-ship missiles. Small and very small UAVs could be effective tools for terrorists – to distribute biological agents or to assassinate very important persons.[8] Later, similar developments are probable with

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[7] In prices of 2004. The rising trend remains, e.g. in 2008 the US alone has spent $76 billion (current $) ($), U.S. Government Printing Office, 2008).

[8] Note that the British special forces were equipped in 2006 with micro aerial vehicles (Wasp, wingspan 40 cm) carrying a small explosive charge to be used against Taliban in Afghanistan, Leake 2006, see also Hambling 2007.

uninhabited ground and sea/underwater vehicles; large ones rather for regular troops, small ones also for asymmetric warfare and terrorism. As a consequence, it is advisable to consider whether international security – and the national security of individual countries – would be served better by preventing or limiting such systems in the first place, that is, by preventive arms control.

Even though the world is no longer characterised by two superpowers with conflicting ideologies, the basic mechanisms of arms races are still at work – now between more participants – , so that preventive limitation of dangerous new weapon technologies still makes sense. In particular, prohibitions among states would go a long way in preventing terrorist access to technologies and systems that they cannot develop on their own.

Preventive arms control needs to be prepared by interdisciplinary research, proceeding in four steps:

1. Prospective scientific-technical analysis of the foreseeable applications – properties of the respective technology, in case of a weapon: propagation, effect on a target subject or object; in case of new civilian activities: potential for diversion of militarily usable substances.
2. Prospective analysis of military and operational aspects – probable use, against which targets; unusual employment forms, potential for collateral damage.
3. Assessment of both results under the criteria of preventive arms control. In case of a negative judgement:
4. Consideration of options for limitation and of means and procedures for verification of compliance, with balancing of positive uses that should not be overly restricted and of the effort needed for implementation and verification.

In the ideal case then states would meet and negotiate on the basis of this analysis. If an agreement is reached, it has to be implemented and later, if necessary, adapted to new developments.

In a systematic treatment, the criteria of preventive arms control have been categorised in three groups (Neuneck & Mölling, 2001; Altmann, 2006, Ch. 5):

I. Adherence to and further development of effective arms control, disarmament and international law

1. Prevent dangers to existing or intended arms-control and disarmament treaties
2. Observe existing norms of humanitarian law
3. No utility for weapons of mass destruction

II. Maintain and improve stability

1. Prevent destabilisation of the military situation
2. Prevent technological arms race
3. Prevent horizontal or vertical proliferation/diffusion of military-relevant technologies, substances or knowledge

III. Protect humans, environment and society

1. Prevent dangers to humans
2. Prevent dangers to the environment and sustainable development
3. Prevent dangers to the development of societal and political systems

4. Prevent dangers to the societal infrastructure.

Whereas groups I and II deal with the prevention of armed conflict or how it is waged, group III concerns dangers arising in peacetime – e. g. by new pollutants or systems which could proliferate to terrorists.[9]

3. Assessment of Uninhabited Vehicles under the Criteria of Preventive Arms Control

An in-depth analysis of the various potential types of uninhabited military vehicles under the criteria of preventive arms control still needs to be done. Here, a first short assessment will be given, pointing at the most burning problems as seen today, looking at the criteria in sequence.

Arms Control and Disarmament (I.1)[10]

Whereas there are no arms-limitation agreements that directly treat uninhabited military systems, several have a bearing on them. For example, the Biological Wesapons Convention of 1972 and the Chemical Weapons Convention of 1993 ban the respective weapons, so that uninhabited vehicles must neither carry containers nor release mechanisms for such agents. As long as there are no intentions or preparations to equip uninhabited vehicles with such there is no danger to these conventions.

In the realm of nuclear weapons, the Intermediate Nuclear Forces Treaty of 1987 between the USA and USSR/Russia bans ground-launched ballistic missiles as well as ground-launched cruise missiles with ranges between 500 and 5,500 km (air- and sea-/submarine-launched cruise missiles are not affected). If uninhabited aircraft (having a range in this interval) would be equipped with nuclear weapons, the respective country would certainly argue that these would not constitute cruise missiles and would thus not be constrained – note that the USA has argued that cruise missiles are no unmanned vehicles (Department of Defense, 2007, p. 1). In this way, the Treaty could be undermined. Another problem is that there is no comparable treaty binding other countries.

The Strategic Arms Reduction Treaties of 1991 and 1993 limit strategic nuclear weapons and their carriers, namely ballistic missiles, cruise missiles and bomber aircraft. These treaties as well as the follow-on Strategic Offensive Reduction Treaty of 2002 do not contain rules for other/newer types of uninhabited vehicles. In particular uninhabited aircraft could be used to carry nuclear weapons, possibly circumventing limits on cruise missiles as well as on bomber aircraft.

The Treaty on Conventional Armed Forces of 1990 limits the holdings in five major weapons classes for the NATO member states and Russia; its definitions of battle tanks, armoured combat vehicles, artillery, combat aircraft and attack helicopters intentionally do not mention personnel on board, so that uninhabited versions would fall under the same rubrics, would count in the national holdings, would have to be

[9] These criteria and the following considerations go beyond the list of issues given by Lin et al. (this volume).

[10] The number in brackets at the end of the headlines refer to the criteria of preventive arms control presented on page 73.

notified to the Treaty partners, would be subject to inspection etc. However, one can foresee a debate which types of armed UAVs would constitute a combat aircraft. Whereas the definition is quite general,[11] arguments might be made that converted surveillance drones or very small uninhabited aircraft do not fall under this heading. The situation with respect to "combat helicopters" is similar. The definitions of a "battle tank" and "heavy armament combat vehicle" contain mass thresholds (16.5 tons and 6.0 tons, respectively) so that potential future uninhabited combat vehicles with lower masses could fall outside of these traditional categories. Thus, a grey area of uncounted and unlimited combat systems might develop. A fundamental problem is that similar limitations of conventional armaments are not in force in other continents.

The Outer Space Treaty of 1967 prohibits nuclear weapons and other weapons of mass destruction in Earth orbit, independent of the presence of a crew on a satellite or space station.[12] However, other weapons are not legally banned, even though the international community votes for the prevention of an arms race in outer space consistently since decades (e. g. United Nations, 2008). Whereas there is a certain restraint in developing and testing hit-to-kill anti-satellite weapons, recent plans for docking, servicing and manipulation satellites/space robots, generally without crew, open new possibilities for attacks on satellites, endangering progress towards the long-sought-for general prohibition.

It is worthy of note that some uninhabited vehicles are included in export-control regimes. The Missile Technology Control Regime with 34 participating states restricts exports of ballistic missiles as well as cruise missiles and UAVs (and their components) which can carry 500 kg or more over 300 km or more; UAVs are included independent of the payload, and even independent of the range, if they have autonomous or long-range remote-control navigation and equipment to spray aerosols. The Hague Code of Conduct with 129 member states deals only with ballistic missiles and asks for restraint in exports. The Wassenaar Agreement of 40 member states restricts exports of armament technologies and sensitive dual-use technologies many of which are relevant for uninhabited vehicles. While these measures have a limiting effect on horizontal proliferation,[13] export controls suffer from the principal problems that not all countries participate and that the possessor countries do not restrict their own use and further development of the respective systems and technologies.

3.2. International Humanitarian Law (I.2)

As demonstrated with the by now routine uses of armed UAVs (Predator, Reaper) by the USA in Afghanistan, Iraq and Pakistan, in many cases the principle of discrimination in warfare is violated – civilians are attacked and killed (see the examples given by Weber, this volume). One can make the point that by not being on the scene, with the main information provided by video images, remote-control attacks are prone to errors from misjudgement. In addition, the far-distant office environment

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[11] Art. II, Section 1, Par. (K) states: „The term 'combat aircraft' means a fixed-wing or variable-geometry wing aircraft armed and equipped to engage targets by employing guided missiles, unguided rockets, bombs, guns, cannons, or other weapons of destruction, as well as any model or version of such an aircraft which performs other military functions such as reconnaissance or electronic warfare. The term "combat aircraft" does not include primary trainer aircraft."

[12] Ballistic missiles which only temporarily travel through outer space are not affected.

[13] Horizontal proliferation means spread of an existing technology/system to additional countries, vertical proliferation denotes qualitative change within countries.

and computer-game-like interface make it easier to press the button than if the soldier is on the scene, having to pull the trigger of a rifle in front of the victim (Cummings, 2004; Weber, this volume).[14] A soldier on the ground can check the identity, search for weapons and arrest a person – all this is impossible using a remotely controlled aerial vehicle.

Even more problematic would be autonomous decisions by armed uninhabited vehicles about when and whom or what to attack. Killing humans by machine decision raises a fundamental ethical problem. One issue is the possibility of technical failure which could take many forms. Another challenge is compliance with the international humanitarian law which is required for all means and methods of warfare. For autonomous armed systems to be allowed, their capability to discriminate between an active combatant and one who is *hors de combat* (e.g. unconscious or surrendering), between a combatant and a civilian who is to be saved, or to weigh military advantage against collateral damage would have to be at the same level as that of a human soldier (Sharkey, 2007, 2008). Such a capability of algorithms to judge on very complex, fast-varying situations at the human level is far from the present state of "artificial intelligence" and might not be achieved even after several decades.[15]

Weapons of Mass Destruction (I.3)

Uninhabited vehicles could be used as carriers of weapons of mass destruction. Whereas biological and chemical weapons are prohibited by comprehensive conventions (see above), nuclear weapons are not (yet) outlawed.[16] Principally, nuclear weapons could be transported by uninhabited vehicles in all media, but nuclear-armed submarines as well as surface ships will likely continue to be operated by a crew. Land vehicles with nuclear weapons on board would pose problems for the military – they might be seized and they would take considerable time for longer distances; ballistic or cruise missiles (for few tens of km, also artillery grenades) would be preferred. The most likely nuclear-weapon carrier would be uninhabited aircraft. In the form of cruise missiles they exist already, but future uninhabited combat aircraft (re-usable, taking off from runways, not from launchers) might also be equipped with nuclear gravity bombs or stand-off missiles.

Destabilisation of the Military Situation (II.1)

In the given context "destabilisation" refers to increasing motives or pressure to start a war or to attack. In particular some UAV will be capable of deep penetration into enemy territory and precision surprise attack. At low altitude and slow speed they are very difficult to detect; comprehensive defence against such vehicles does not yet exist. Because there is no crew on board, they could be sent more easily and for more

[14] Of course, some such effect exists already with weapons launched or released from a distance, but the office workplace reached by commuting from home means a much higher emotional remoteness from the battlefield.

[15] "To use robot technology over the next 25 years in warfare would at best be like using the BLU-108 submunition – i. e. can sense a target but cannot discriminate innocent from combatant." (Sharkey, 2008a)

[16] But note: Article VI of the Nuclear Non-Proliferation Treaty of 1968 obliges the State Parties to negotiations towards nuclear disarmament. High-ranking former US officials are since 2007 calling for a world free of nuclear weapon (Shultz et al.,2007, 2008).

dangerous missions – loss or imprisonment of a pilot is excluded. Destabilisation could also result if the attacked side would be uncertain if the vehicles carry weapons of mass destruction.[17]

Pressure to attack is particularly relevant in a crisis; if acting too late could mean a decisive disadvantage in armed combat which is seen as imminent, this would create strong motives to act fast. Such a situation can be foreseen whenever uninhabited combat vehicles of two potential opponents would meet at short distance, be it along a border or in international territory. Conceive of two fleets of such aircraft, watching each other intensely for indications of the start of hostilities. Because a co-ordinated attack by one side could wipe out a significant portion of the systems of the other, they would be on high alert. Any sign of attack – maybe a sun reflex mistaken as exhaust flame from an anti-aircraft missile or a computer error – could trigger actual shooting. With uncontrolled feed-back cycles between the two systems of warning and attack, war could start even though both sides would not want it. With pilots on board, some better judgement of context and waiting whether a threat is real can be expected – however, with humans in control there is a danger of brinkmanship. It is important to realise that in such a situation remote control with its communication and reaction delay may be too slow to ensure survival of one's own combat systems. Thus, if fleets of uninhabited combat vehicles will be built by several countries, a strong motive would ensue to delegate firing authority to the systems themselves. A second motive stems from the intent to have one soldier control many uninhabited combat vehicles.

Nervousness about the state of one's own central military systems with the accompanying instability can result from several other potential applications of uninhabited vehicles. One is small satellites which could dock and manipulate important satellites of an opponent. They could destroy the capability for strategic warning, surveillance and communication on short notice. A more remote future scenario is micro-robots entering military systems of a potential opponent covertly, sitting there unnoticed, ready to disrupt the electronics at any time.[18] Swarms of highly precise conventionally armed small UAVs might even be used to disrupt nuclear-strategic targets, carrying the instability to the level with the highest consequences. The outlook of a conventional strike removing a significant part of the opponent's nuclear retaliatory capability could lead both sides to very dangerous behaviour.[19]

Technological Arms Race (II.2)

A qualitative arms race is obviously already taking place today with UAVs, while the vast majority of systems is still unarmed. As stated above, several countries are developing UCAVs, and the USA already has deployed UAVs equipped with missiles, using them routinely in Iraq, Afghanistan and Pakistan. One need not be a prophet to foresee that other strong military powers will follow suit. The race will encompass

[17] This holds if there is fear of chemical and biological weapons on board; for nuclear weapons deterioration will occur if the there are more nuclear-capable uninhabited aerial vehicles than piloted nuclear-capable aircraft.

[18] Such a scenario, originally ascribed to US forces acting against others, was wrongly described as part of Chinese military strategy (Pillsbury, 2000, Ch. 6) as related in: Altmann & Gubrud (2004) and Altmann (2006, Section 3.4.).

[19] On conventional precision attack against nuclear-strategic installations see Miasnikov, 2000.

materials, engines, communication links, and software. Technological edges will be temporary, e.g., in developing the capability for aerial combat.[20]

Similar developments over time are probable with sea systems (under water and on the surface) and with land vehicles, should the latter prove sufficiently militarily effective and cost-efficient.

Horizontal or Vertical Proliferation (II.3)

Horizontal proliferation (that is, to other countries) of technologies and systems can already be observed with unarmed UAVs – by now over 50 countries use, produce or develop them and 20 countries export them. Three countries (USA, Israel, Iran) possess armed UAVs (Jane's 2007). In the future, the world will see more exports, including to crisis regions. One example is the Iranian Ababil-T (with 45 kg explosive) which was launched against Israel by the Hezbollah in Lebanon in 2004 and 2005 (Jane's 2007, p. 75 f.). Horizontal proliferation can also take the form of collaborative development, such as between Israel and India for three types of UAV (Raghuvanshi 2005).

Vertical proliferation, the qualitative improvement of military technologies or systems, can be observed in many countries, again with UAVs. The big next step – already taken by the USA – is arming them, the following one will be to build dedicated uninhabited combat aircraft for all missions now reserved for piloted craft, such as bombing or air combat. Depending on development success, horizontal and vertical proliferation can arise with uninhabited vehicles in other media, too.

Dangers to Humans (III.1)

If uninhabited systems developed for the military will proliferate widely, some of them could find their way into the hands of criminals. This will not so much apply to larger, expensive systems such as UCAVs, but small UAVs would make ideal terrorist tools. With wing spans of 1-2 m several kilograms of payload could be carried, micro aircraft measuring tenths of a metre could transport tens of grams. While such limited payload could not do much damage in the form of explosive, mass destruction could be achieved by chemical and in particular biological agents. Even small amounts of explosive could have strong effects if important persons were attacked. Assassination of high-level politicians could also be achieved by simple mechanical hit, or by injecting a poison.

Air vehicles will usually be the most practical option, but water or land systems could also be used by terrorists and other criminals, e. g. a small robot crawling up the wall of a building, penetrating a window and delivering an explosive charge to the person(s) inside.

These dangers would be the higher the better military systems would have already been designed for such purposes. However, many uninhabited systems will be universal – various special-purpose modules can be put in or strapped on.

[20] The capability of air combat is foreseen in US planning for 2020-2025 (Department of Defense, 2007, p. 3).

Dangers to Environment and Sustainable Development (III.2)

This area is not very relevant here. The only exception would be things such as unintentional releases of (new) chemical or biological warfare agents prepared for dispersal by uninhabited systems. However this is not strongly linked to the carriers, rather it is a function of whether the corresponding conventions continue to be complied with. Specific new dangers from fuels or other energy supplies do not come in sight. Consumption of resources will not be a big issue either.

Dangers to Societal and Political Systems (III.3)

Societal and political systems could be endangered by uninhabited systems used for terrorism, as discussed in III.1. A different problem exists with such systems used for eavesdropping on people and for industry espionage. This will become the more relevant, the smaller robotic systems will become. In 10 or 15 years, micro-robots might be able to covertly crawl through the crack under the door, or fly through a partially open window (Altmann, 2006, Section 6.1.3.3). Already today drones with cameras can be rented – they can fly over a wall or fence, taking photographs inside a closed area.

Dangers to Societal Infrastructure (III.4)

As mentioned with III.1, terrorists could get access to certain types of uninhabited systems. Those with many kilograms of payload could be used to directly damage or destroy infrastructure installations (such as electric-power switching stations, water works). Smaller systems could be aimed at central control and communication components – antennas, control stands etc. Smaller ones could also be used to provide intelligence for later attacks by larger systems or a group of people.

These considerations show that there are strong reasons for concern about military robots/uninhabited vehicles, in particular about armed ones. Small ground vehicles which are remotely controlled over tens of metres, such as the ones used to inspect and destroy improvised explosive devices, seem harmless at first sight, but could become dangerous if they will be armed and autonomous or controlled from far away. On the international level, the biggest problems arise with respect to the laws of warfare and from destabilisation and proliferation. These concern military systems of all sizes. Within societies, the most important issues arise from smaller, cheaper, more easily accessible systems that would be used by terrorists or other criminals.

4. Preliminary Recommendations

A detailed analysis of military uses of robots/uninhabited systems within the framework of preventive arms control still has to be done. Future research will have to study the military-civilian overlap and the balancing of civilian benefits versus military risks, and to analyse options for limitation and verification of compliance. This will likely become more difficult if and when robots/uninhabited vehicles will increasingly pervade the public sphere. At present, some general thoughts based on Altmann (2006, Chs. 6, 7) can be given:

- Due to the several positive uses an outright prohibition of all types of robots/uninhabited systems is not justified, but the most dangerous military uses should be prohibited preventively.
- In order to prevent circumvention by civilian robots/uninhabited systems, the latter should be included in a limitation and verification regime.
- In order to keep the intrusiveness of verification limited and to allow it to be carried out without special equipment mostly, very small robots/uninhabited systems should be prohibited at all, with a size limit of 20 to 50 cm. (Narrowly constrained exceptions might hold for important applications, e.g. exploration of shattered buildings.) Thus, one could rely on on-site inspections as e.g. under the Treaty on Conventional Armed Forces in Europe. Satellite monitoring could contribute additional information at least for larger systems and their infrastructure.
- Unarmed robots/uninhabited vehicles above this size for military uses or for civilian purposes should be regulated and limited numerically.
- Beyond the existing uninhabited carriers (ballistic and cruise missiles), nuclear weapons on other types of robots/uninhabited vehicles should be prohibited. The existing carriers should be reduced within a re-started process of nuclear disarmament.
- Uninhabited satellites as or with weapons should be prohibited in the framework of a general ban on space weapons. Docking and manipulation satellites should be regulated internationally.
- Armed robots/uninhabited vehicles should be prohibited outright (except for the one-way ballistic and cruise missiles already existing). This would mean withdrawal of a few systems which are already deployed, mainly on the part of the USA (Predator, Reaper). For most other countries the prohibition would affect only future systems which should make agreement easier. In case such a ban will not be attainable, the international humanitarian law should be augmented by a specific rule prohibiting autonomous machine decisions on whom or what to attack, absolutely demanding a human in the decision chain.

In order to be comprehensive and to put up a high barrier against fast break-out, the prohibitions recommended above should hold for the stages of development, testing, deployment and use.

5. Conclusion

Whereas military UAVs for surveillance already are deployed by dozens of countries, providing them with weapons has only begun recently. If unchecked by preventive arms control, this process will spread to many more countries. Later, similar developments are possible in uninhabited vehicles on land, on and under water and – to a more limited extent – in outer space. Seen from a narrow standpoint of national military strength, these developments will provide better possibilities to fight wars and to prevail in them. However, if one looks at the international system with its interactions, the judgement will be different, in particular concerning armed robots/uninhabited systems. Destabilisation and proliferation could make war more probable, including between great/nuclear powers. Criminals and terrorists could get more potent tools for attacks, too.

With an enlightened understanding of national interest, countries could come to the conclusion that international preventive limitation of the most dangerous types of uninhabited vehicles should be pursued. Here, the USA plays a pivotal role; it will have to reduce its push for military-technological superiority to gain better security in the future.

Roboticists and artificial-intelligence researchers should be aware of the military developments and their dangers, should speak out against hostile uses of the results of their work and should support international limits.

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