

# Limiting Military Uses of Nanotechnology and Converging Technologies

Jürgen Altmann

Experimentelle Physik III, Universität Dortmund/Bonn International Center for Conversion

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## Introduction

Nanotechnology (NT) is linked to many kinds of hopes – and fears – due to its potential for radical change in how we live, work, communicate, even who we are, in particular through the convergence with other technologies and sciences, such as biology, computer science, cognitive science, social science and more (“converging technologies” (CT), Roco/Bainbridge 2003, Roco/Montemagno 2004, High Level 2004). In order to understand benefits and risks and to help in steering NT development and use, technology-assessment institutions have begun to study NT; in Germany, e.g., the Office for Technology Assessment of the Federal Parliament (TAB) has published a major study in 2003 (Paschen et al. 2003).

If NT will lead to an industrial revolution in general, this will affect all areas of technology use. A specific sector is formed by the armed forces; in the industrialised countries they have used new/high technology since many decades to achieve victory in armed conflict. Even though it is well known that the armed forces prepare for violence and destruction, including mass destruction (e.g. in the official and unofficial nuclear-weapon states), military use of new technologies is not often included into technology assessment.<sup>1</sup> One reason may be that war is seen as extreme exception so that the impact of military technologies on society are minor. This is problematic, however: First, military technologies could have direct or indirect effects on civilian life even in peace time. Second, if new military technologies would make

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1 The German TAB is somewhat exceptional in that its NT report has small sections discussing military/armament/security aspects (Paschen et al. 2003, Sections IV.2.8, IX.3.3, X.6) and in that it has done earlier a general study of preventive arms control (Petermann/Socher/Wennrich 1996/1997).

war more likely, the affected societies would suffer more. Since military and civilian technologies increasingly overlap and since there are various direct and indirect interactions between both sectors, technology assessment of NT should systematically include military uses (and misuses). Control of technology development and use should comprise both, the civilian and military sectors, to avoid undermining of limits.

In a first systematic perusal of potential military uses of NT, I have found several applications that could produce serious dangers – for international security, for security in societies or for human nature (Altmann 2004, i.p.). In the later sections, I describe these applications and present recommendations for their preventive limitation (see also Altmann/Gubrud 2004, 2004a). In order to set the stage, I start with general remarks on the military and its use of high technology and cast a look at military research and development of NT in the USA.

### **Military Use of High Technology**

While superior technology has been a decisive factor in wars in all of history, it was only in the last century that the armed forces incorporated science into their organisation in a systematic way. In particular after World War 2, rich/large/leading nations built up big centres for military research and development (R&D) and funded innovation in military industry on a large scale. Much of this was connected to nuclear weapons and their carriers, but increasingly was carried over to all other areas of warfare.

Armed conflict is about breaking the will of an opponent by violent force. The law and rules of civilian society – that exclude pursuing one's will by force – no longer apply. Only the law of warfare poses some limits on how force is used; in peace time, agreed arms limitations can reduce the likelihood of war and restrict the number and quality of its tools. Success in armed conflict depends on many factors, among them technology, strategy, morale and surprise. Since highest national values may be at stake, there is an immanent tendency to circumvent the rules in order to prevail. In peace time, there is a motive to covertly compile more armaments than what arms-control agreements stipulate. This emphasises the importance of verification of compliance. In actual conduct of war, on the other hand, compliance with the international law of warfare depends on the spirit of a force; public scrutiny, experience with rule-keeping by the opponent, but also the fear of reprisal play a role. When armed conflict is

raging, there is no reliance on the law of warfare; the necessity of prosecuting war criminals by international courts is only too obvious.

Since technology increasingly provides advantages in battle, all potential opponents have strong motives to stay in the lead, or at least to keep the lag small. New fields of technology make possible new ways of destruction. Military exploitation of new technology means putting the new possibilities into practice: researching the potential, developing and testing devices. Sometimes international law or arms-control treaties impose limits – e.g. the Biological and Toxin Weapons Convention of 1972 prohibits all non-peaceful uses of biological agents and toxins, including development and testing. Offensive biological weapons are prohibited thus, whereas defensive protection (such as gas masks, vaccination) is allowed. However, in principle an opponent might break the rules covertly and achieve victory in this way. Thus, there is a strong motive to understand what such an opponent could bring to bear in order to be prepared to counter such development. As a consequence, even a defensive-minded state can feel a need for some R&D of the forbidden offensive weapons. In such a way, scientific-technical advance has a tendency to undermine agreed limitation treaties. The only ways to contain this danger between potential opponents are 1) reliable verification of compliance with existing agreements, and 2) early conclusion of treaties for new technologies, that is preventive arms control.

A central means of securing effectiveness in combat is secrecy. Knowledge of technical details, strategies, plans, even the motivation of an opponent's armed forces makes attacking them easier, thus there is a strong motive to keep such information secret on the own side – and to gain it by espionage on the others. There can be many additional motives for secrecy, and states differ widely how they handle it. The more secretive an armed force is, the higher is the possibility of a covert breakout: massing of weapons or personnel, introduction of qualitatively new weapons so that one side would suddenly dominate militarily. This problem becomes more urgent if new technology promises revolutionary change, as is the case with NT. Again it points at the necessity of supporting agreed limits by reliable verification, but it also emphasises the need to balance the required transparency with the (perceived) need for secrecy.

When potential military opponents prepare for the possibility of war by using new technology, small differences in technology can lead to high differences in the outcome. It is

relative differences that count mostly. Shooting somewhat faster, at somewhat longer range, looking somewhat farther etc. can all mean that one's systems survive whereas the other's are destroyed. This explains the race for the "leading edge" and the high price that the military are prepared to pay for new technology. It makes agreement on limitations more difficult. However, there are additional factors; e.g. a more defensive orientation can give more tolerance.

Mainly because of their very task – prevailing in armed conflict by selective or massive destruction – the armed forces want to prepare many of the bad and ugly uses of new technologies that civilian society will try hard to preclude. Criminal development of such prohibited uses – new poisons, eavesdropping equipment etc. – within society is severely restricted. Access to laboratories, expertise, testing grounds etc. is very difficult if one has to work clandestinely, under permanent threat of prosecution. On the other hand, in military R&D such activities are carried out in an organised manner under the protection and with the resources of the states. This sets a conceptually different framework for technology assessment and subsequent regulation.

Within societies, there is a higher authority with the monopoly of legitimate force that protects sub-state actors from attacks by others and prosecutes perpetrators. The international system, on the other hand, can still be characterised by the security dilemma. There is no overarching authority with a monopoly of force – states try to make themselves secure by their individual armed forces. Usually, strengthening the latter increases the mutual threats, leading to motives for further strengthening. If unchecked, the net outcome is decreased security of all.

There are several ways out of this security dilemma – they are mutually reinforcing. One is voluntary agreement limiting the mutual armed forces (arms control). Since the armed forces keep their task of prevailing in war, should it occur, there is an obvious friction between the motives for limitation and the motives for combat effectiveness. Nevertheless, an enlightened view of national security should lead to the preference of mutual limitations. A second alternative is restructuring of the armed forces so that combat efficiency is high in static defence of the own territory, but is low in attacking others. A third way out of the security dilemma is political détente, economic co-operation etc. so that one could not gain from an attack and it would become politically/culturally unthinkable. Finally, states could develop the

United Nations to the international authority with monopoly of legitimate force similarly to the one that governments represent within states.

### **Military R&D of NT in the USA**

After the Cold War, the USA has remained as the undisputed leader in military high technology. The USA spends about two thirds of the global expenditure for military R&D, \$ 52 billion of about \$ 80 billion in 2002, and marked increases are planned (BICC 2003: 48, 2004: 54). In NT proper, one quarter to one third of the Federal R&D money in the National Nanotechnology Initiative (NNI) goes to the Department of Defense (2003: \$ 243 million of \$ 770 million) (Altmann i.p.: Section 3.1). (There is not yet a special programme for CT.) This money is used for a great variety of activities, mostly at the stages of basic research, applied research and advanced technology development. Work is being done at universities, the laboratories of the armed services and the national weapons laboratories, on topics such as carbon nanotubes, magnetic nanoparticles, organic light-emitting diodes for displays, bio-computing, bio-molecular motors. Closer to military needs are projects in sensors for chemical- or biological-warfare agents or nanostructured explosives and armour.

Development of systems that could actually be deployed is still many years off. In an effort for more targeted research and earlier introduction into service, the Army is funding the Institute for Soldier Nanotechnologies that was founded 2002 at the Massachusetts Institute of Technology, with \$ 50 million over five years (plus additional \$ 30 million from industry). Here, up to 150 people are working in seven multidisciplinary teams. One overarching goal is a battle suit that protects against bullets, chemical and biological agents, provides cooling or heating, monitors body functions, compresses wounds and applies medicines.

In conferences of the NNI, various goals were given for “National Defense” or “National Security” uses of NT and CT (Roco/Bainbridge 2001: ch. 2, Roco/Bainbridge 2003: section E). Among them are:

- miniature sensors, high-speed processing and communication,
- sophisticated virtual reality systems for training,
- uninhabited combat vehicles,
- higher performance in military platforms,

- improved chemical/biological/nuclear sensing and casualty care,
- improved systems for nuclear non-proliferation monitoring and management,
- devices for control of nuclear systems,
- enhancement of human performance,
- a brain-machine interface.

Other countries are spending much less for military R&D of NT. A cautious estimate is that the US expenditure is four to ten times the amount of all other countries combined. However, this could change when other states that are active in military high technology would follow the US example and make military NT a matter of high priority. By leaving to the USA the task of trying many avenues and sorting out the more promising ones, such countries could not acquire a leading position, but might nevertheless get relatively more military effect for the same amount of R&D spending. There is little doubt that countries which are capable in NT in general could also develop and introduce military NT applications, following the US lead with several years delay.

### **Potential Military NT Applications**

NT could be used in all areas of fighting and preparing war. Small but powerful computers will be built into weapons, uniforms, equipment, vehicles etc. Larger computing systems will be applied in battle management and logistics, increasingly taking over tasks that used to be reserved for humans. Small, sophisticated sensors could become cheap enough to be scattered in high numbers. Missiles will become smaller, guidance systems could be provided even for small munitions. NT-based fibre composites could allow metal-free small arms and ammunition. Vehicles will become lighter and more agile, engines more efficient. Autonomous vehicles for all media will become possible, for reconnaissance and communication, but also for combat. For outer space, satellites and their launch rockets could become much smaller and cheaper; they could form anti-satellite weapons working by direct hit or manipulation after docking. Some autonomous systems may be very small (centimetres, later millimetres and even below); if fully artificial systems will turn out more difficult to construct, modifying/implanting insects or small mammals may provide an earlier solution. Providing neurone contact, bio-compatible materials, small computers and power supplies, NT could be used for implants in soldiers' bodies – for monitoring, communication, expanded

senses or release of drugs. Genetic engineering and biotechnology already *per se* provide options for new chemical and biological warfare agents that are resistant against antibiotics or suppress the immune system (e.g. Nixdorff et al. 2003). NT will likely accelerate such possibilities and create new ones, generically by new analysis and manipulation tools. Directly utility will come with the advances that will be made in individualised and targeted pharmacology, such as nanoparticles for ferrying agents across the blood-brain barrier, organ-specific binding or *in-vivo* recognition of DNA patterns. The latter may lead to selective action, removing much of the traditional military hesitation towards biological agents because the own forces and population could be infected, too. On the other hand, NT-based sensors and filtering/neutralising materials could be used for better protection against chemical or biological agents.

### **Preventive Arms Control: Concept and Criteria**

In order to provide a framework for assessing militarily relevant technologies, the concept of preventive arms control has been developed (see e.g. Neuneck/Mölling 2001, Altmann i.p.: Ch. 5). The purpose of preventive arms control is to limit technologies before they are deployed with the armed forces, often starting at the development or testing phases. The concept proceeds from the viewpoint of international security, looking at the international system – and is thus different from an outlook that tries to provide national security through military strength. However, if national security is seen in the wider context, this may well lead to acceptance of preventive limits of the own technological capabilities if those of potential opponents will be reliably limited likewise. Earlier examples include the Anti-Ballistic Missile Treaty (1972-2002) or the Protocol banning Laser Blinding Weapons (1995).

In today's situation, the concern of preventing access by terrorists to certain technologies should provide additional motives for preventive arms control. Of course, terrorists cannot be partners of limitation agreements, but their own capabilities of making use of new technologies are quite limited; much more likely is access to technology that would have been developed and produced by states.

Beside agreed limitation (arms control proper) – earlier in many cases bilateral, then increasingly multilateral –, there are also unilateral steps that can be taken. If the situation is

very asymmetric, a technology leader can renounce a certain principal possibility without danger. As long as comprehensive agreements will not be in effect, export controls by the most advanced nations – a form of multilateral unilateralism – will be useful to limit the spread of new military technology to countries that may not be inclined to enter agreements. However, export controls are discriminatory and create motives for circumvention – universal agreed limitation is clearly preferable, even if a few outsiders may remain.

Preventive arms control consists of four steps: (1) prospective *scientific-technical analysis* of the technology in question; (2) prospective analysis of the *military-operational aspects*; (3) assessment of both under the *criteria of preventive arms control*. If the latter leads to the result that action is recommended, (4) possible *limits* and *verification* methods need to be devised. The criteria can be sorted in three groups:

I. Arms control, disarmament and international law:

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

II. Stability:

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

III. Protect humans, environment, and society:

- Prevent dangers to humans,
- Prevent dangers to environment and sustainable development,
- Prevent dangers to the development of societal and political systems,
- Prevent dangers to the societal infrastructure.

The readiness to enter preventive arms control and the extent of limitations will be influenced by the military posture of the respective state. The tasks given to the armed forces may differ widely, the spectrum may range from large-scale armed conflict everywhere on the globe via defence of the own territory, crisis intervention and peace enforcement to defence against terrorist attacks. With its priority on international security and agreed limitations, preventive arms control is inclined towards reducing military threats and offensive potential. It makes

sense on all levels of the military-posture spectrum. Without it, the more offensive postures could become more dangerous over time.

With preventive limits in effect, there is the principal possibility of clandestine breakout. This has to be assessed in advance and precautions have to be taken. In the technology areas regulated specifically, this can be done by appropriate rules and methods of verification of compliance. Since science constantly moves into the unknown, the advances need to be monitored continuously, e.g. by an international body comprising scientists, military and disarmament professionals. Wherever problematic military applications appear on the horizon, military-technology assessment should start and adequate specific limits with appropriate verification should be developed, if needed. Such an approach could also solve the problem of dual use; civilian R&D needs to be included from the beginning into monitoring, assessment and, if necessary, limitation.

Since states have to enter arms-limitation treaties voluntarily, they will only do so if they are convinced that the agreements are in their best interest. In pondering the arguments for and against, not only the military should be heard; scientific analysis and an enlightened public should play an important role.

### **Assessment of NT under Criteria of Preventive Arms Control**

In my assessment of the potential military NT applications under the criteria of preventive arms control (Altmann i.p.: Ch. 6), I have found several that do not pose strong dangers or that are so close to civilian uses that limitation would be impractical. This concerns the more generic applications such as computers or materials. A few military uses could help to protect against terrorist attacks (sensors, filters, decontamination agents) or would improve the verification of existing treaties (certain sensors). These are rather judged positive.

On the other hand, there are several potential military NT uses that raise flags in the criteria groups:

I. Arms control, international humanitarian law:

New types of chemical or biological weapons would violate the Chemical Weapons Convention (CWC) or the Biological and Toxin Weapons Convention (BTWC). R&D in

these directions could undermine these conventions over time. Particular problematic is the fact that the BTWC – different from the CWC – that does not yet include a compliance and verification protocol.

NT-enabled lighter combat vehicles could evade the definitions of the Treaty on Conventional Armed Forces in Europe (where, e.g., a “main battle tank” is defined to have a mass above 16.5 metric tons).<sup>2</sup>

Autonomous combat vehicles – seeking their targets by themselves and attacking them – would violate the international law of warfare because they would for quite some time not be able to differentiate between combatants and non-combatants or to recognise combatants *hors de combat*.<sup>3</sup>

## II. Stability:

Military stability between potential opponents could be decreased by NT-enabled small, highly precise weapons that enhance offence. Small missiles (size maybe 0.3 m) could be cheap and used – against aircraft, communication nodes etc. – in high numbers. Particularly worrisome would be small ballistic or cruise missiles (say, 1 m length) that due to their extreme precision (say, 0.1 m accuracy) were capable of attacking nuclear-missile silos and strategic command centres with a non-nuclear payload.

Nervousness would rise with micro-robots that could covertly invade military systems and strike from within at any time.

Autonomous combat systems at close mutual range (at sea, in outer space) would need to react fast, creating the possibility of uncontrolled escalation.

Arms races are likely in all areas of military NT use.

Technologies for light vehicles, small missiles, precision guidance, biological agents etc. will spread. If NT-based military systems will become small and cheap, proliferation will be difficult to control.

## III. Humans, environment, society:

Dangers to humans and society in peace time would arise if new chemical or biological warfare agents would get into the hands of criminals and terrorists.

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2 The definition could of course be updated easily by the Treaty Parties as new light-weight combat vehicles would arrive. The main problem would be to ensure that this actually happens and is not blocked by states that hope for military advantage, maybe outside of Europe.

3 The “smart” weapons of today are a step into this direction, but in their case the target has been defined and the firing decision made by a human operator. The target is still found in a relatively simple manner – e.g. by fixed co-ordinates (cruise missile), with human-operated designation (laser-guided bomb), by special vehicle signature after arrival in a human-specified area (anti-tank submunition).

Small arms and munitions made from nano-fibre composite without metal would evade existing x-raying and metal-detection equipment, making criminal and terrorist attacks easier. NT-based materials, propellant and guidance may allow missiles of less than 0.5 m size that could take civilian airliners down.<sup>4</sup>

Privacy could be invaded if small sensors or robots, originally made for the military, would make their way into society.

Should the armed forces rush ahead with manipulation of soldiers' bodies, civilian society would be faced with *faits accomplis* that would pre-empt the needed fundamental debate how to deal with the potential of modifying the human condition.

The following table shows a summary view of the potential military NT applications that are particularly dangerous together with the criteria groups that are affected (for a differentiated presentation see Altmann i.p.: Ch. 6).

Criteria group Potential application	Arms Control / International Humanitarian Law / Weapons of Mass Destruction	Military Stability / Arms Race / Proliferation	Humans / Environment / Society / Infrastructure
Distributed small sensors		X	X
Metal-free firearms		X	X
Small missiles		X	X
Implants and other body manipulation		X	X
Autonomous combat systems	X	X	
Small robots	X	X	X
Small satellites and launchers	X	X	
New chemical/ biological weapons	X	X	X

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4 Such systems could be much more easily hidden and transported than present so-called man-portable air-defence systems (MANPADS), such as the US Stinger with 1.5 m length and 16 kg mass. Having provided Stinger systems to the Mujahideen fighting against the Soviet Army in Afghanistan, the USA has later carried out a buy-back programme with limited success. Comparable missiles of Soviet origin were used e.g. in the attack on an Israeli airliner in Kenya 2002. Since a few years, the USA has promoted international efforts to limit the proliferation of MANPADs. See e.g. Bolcom/Elias/Feickert 2003, Chankin-Gould/Schroeder 2004.

## Recommendations for Preventive-Arms-Control Action

Since there are strong reasons for concern, certain military applications of NT should be prevented. At the same time, positive civilian applications should not be hampered unduly. However, civilian society will have many reasons to block or control problematic NT applications anyway. Even though this is superficially independent of preventive arms control, there are clear interactions between civilian and military R&D, and the dual-use potential will grow as NT will advance towards manipulation of matter on more fundamental levels. Thus, civilian limits should be co-ordinated with military ones. This calls for an internationally harmonised approach.

Potential limits were considered systematically, together with the effects on benefits of civilian uses and the requirements on verification of compliance (Altmann i.p.: Section 6.4). As a result, no rules tied to NT as such are recommended – NT is just too broad. Rather, specific military missions or classes of equipment should be limited, irrespective of the technology used inside. This follows a tradition in arms control: it is systems and missions that can act destabilising, not technology per se. A second important argument is about verification. Types of equipment designed for specific missions can usually be recognised from the outside; technology-specific limits, on the other hand, would require deep intrusion into the military systems which would be unacceptable.<sup>5, 6</sup> The regulation for applications of NT should be embedded into the already existing framework of arms-control and disarmament agreements and international humanitarian law.

Specifically, I recommend the following measures (Altmann i.p.: Ch. 7):

- Small, self-contained sensor systems below a few cm size should be banned. Smaller sensors are not limited if they form components of larger systems. For important non-military uses, few exceptions might be agreed on, e.g. “bugs” for legal eavesdropping by law-enforcement agencies.

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5 An example would be a fictitious rule not to use carbon nanotubes (as high-strength material, as elements of future high-density computers) in military systems.

6 However, since that NT will make possible small and very small systems, the intrusiveness will have to increase if such systems will arrive. This is another reason for the macroscopic size limits in my recommendations. Even so, microscopes of various types may have to be accepted as on-site-inspection tools. Verification of the Biological and Toxin Weapons Convention will of course need laboratory visits, sample taking, and other microbiological techniques with or without NT.

- Metal-free small arms and ammunition as well as small missiles (below about 0.5 m size) should be banned.
- There should be a ten-years moratorium on body implants and other body manipulation that are not directly medically motivated.
- Pilot-less combat aircraft and other mobile armed combat systems without crew should be banned, with numerical limits on autonomous systems that are unarmed.<sup>7, 8</sup>
- Small robots (below 0.2-0.5 m size) should be banned, with narrowly limited exceptions (e.g. for exploration of collapsed buildings).<sup>9</sup>
- A comprehensive ban on space weapons should be concluded; small satellites (below, say, 1 m size) for other purposes (e.g. earth monitoring or satellite maintenance after docking) – that could nevertheless be used to hit or manipulate other satellites – should be limited in number.
- The Chemical Weapons Convention should be upheld.<sup>10</sup> The Biological and Toxin Weapons Convention should be strengthened by a compliance and verification protocol. Where necessary, clarifying interpretations should be added.<sup>11</sup>

These limits should hold for the civilian and the military sector and start at the stages of development and testing, since it is here where the purpose becomes visible and verification feasible. Deployment and use should of course be prohibited, too.<sup>12</sup>

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- 7 In order to not create too much resistance to such a new rule, existing guided one-way weapons such as cruise missiles should not be affected. The proposal is to use the word “re-usable” in the definition. Since “autonomy” cannot be determined from the outside and could be introduced by a software change, this category should not be used in the legal definition. Differentiation from mines is achieved by the notion of mobility.
  - 8 If it will turn out that re-usable, armed, crew-less systems cannot be prevented (the US drone Predator, retrofitted with a Hellfire missile, has already been used under remote control to destroy a car and kill six putative terrorists in Yemen in 2002), then at least it should be agreed that aiming and weapon release should always be done by a human in the decision loop and that qualitatively new types of nuclear-weapon carriers (such as robots) are banned.
  - 9 The definition should include artificial systems as well as hybrid artificial-biological ones, e.g. rats or insects with implanted control electrodes.
  - 10 Including updating of the schedules of banned and controlled chemicals, as required by scientific-technical advance.
  - 11 In the CWC this would concern potential damaging/incapacitating processes (e.g. electrical, thermal ones) for which some might argue that they do not constitute “chemical action” as required in Art. II. In the BTWC this is about potential (semi-)artificial agents where arguments might be made that they are not “microbiological or other biological agents” as required in Art. I.
  - 12 In a simplified linear model of a military technology, the life-cycle stages are: research, development, testing, production, acquisition/deployment, use, taking out of service. Because during the research stage the later application is usually unclear, preventive limits often exclude research.

With the choices of several centimetres to several times ten centimetres as the lower size limits, verification of compliance can rely mostly on on-site inspections with observation from outside. For chemical and biological agents, however, taking of samples and special analysis equipment will be needed.

The recommendations are geared towards mutual limitations that are agreed internationally by states and will thus affect all partners (more or less) equally. By foreclosing many avenues of production and transfer, they would also have an asymmetric effect on non-participating states and non-state actors – the stronger, the more comprehensive the participation would be. Before negotiations might start and while they might drag along, co-ordinated restraint among the states most active in NT – by tacit or explicit agreement – would be useful. This concerns own development of problematic military systems as well as exports of systems and technologies.

These limits should be co-ordinated with the regulation governing NT use within states as well as with the code of conduct on responsible R&D and use of NT that is beginning to evolve (International Dialogue 2004). The discussions about such a code of conduct should explicitly include the military field.

In order to make the recommendations more concrete and practicable, further work on definitions and delineation as well as on verification details is needed.

The debate on limits of military NT can be much alleviated by transparency in NT R&D. In particular, those states that are traditionally not open about their military R&D should re-think their posture. Restraint in military NT R&D can also help, in particular concerning potential offensive or otherwise threatening uses.

## Outlook

One has to admit that the chances of international agreement along the lines recommended here are not too high. The main problem is presented by the USA, already in its general tradition of striving for a technological edge over potential adversaries. The problem is aggravated by the present US administration with its questioning of arms-control treaties and preparations for preventive war. Thus, convincing the USA to even take part in discussions about preventive limits may be impossible in the coming years.

In such a situation, it may also be difficult to get countries such as China or Russia to agree on limiting their military NT activities. Concerning space weapons, both countries have argued for a ban. Both are active and capable players in NT at large. Information on military R&D is scarce – it seems that at present there is little military NT activity underway. There is no doubt, however, that Russia and China are observing US developments carefully; it is reasonable to assume that they could follow with only a few years delay should the USA decide to deploy new NT-based military systems. Other big arms producers could follow later; exports to many places have to be expected. China and Russia should understand that at least higher transparency would be useful to reduce the influence of suspicion and worst-case assumptions.<sup>13</sup>

There is also a US tradition of mutual, verified limitation of military capabilities. Maybe the prospect of terrorist attacks using the very technologies that the own military might have developed can contribute to strengthen the insight in the USA that restraint and co-operative limits on military uses of NT are in its best interest. A warning example is provided by the Stinger man-portable air defence systems (MANPADS) that were exported to Afghan Mujahideen in the fight against the Soviet occupation, but have been distributed uncontrolled and could be used for terrorist attacks against civilian airliners, as demonstrated with corresponding Soviet systems in Kenya 2002.<sup>14</sup>

Another motive may come from the international debate about a code of conduct for responsible R&D and use of NT that is pro-actively pursued by the US National

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13 One example of US suspicion of Chinese military-NT intentions – created by gross misrepresentation – is documented in Altmann/Gubrud 2004a, Altmann i.p.: Section 3.4.

14 See note 4.

Nanotechnology Initiative (NNI) (International Dialogue 2004). When discussing in this context about prevention of misuse, it would seem illogical to permanently exclude the military aspects. The national debate on societal implications of NT that the NNI is trying to promote could also have a positive influence.

In the European Union and many of its member states, on the other hand, there is a general understanding that arms limitation is an important part of war avoidance. The most dangerous military NT applications do not seem urgently needed for the crisis-prevention and – intervention tasks that EU forces will realistically have to face in the next decade or so. Thus, there is a principal chance that the EU could work for limits on military NT applications. Europe could also act as a role model for other regions of the world and so help to create an international climate favourable to limitations. Similarly to the Anti-Personnel Mine Convention (1997) or the Kyoto Protocol (1997), it may even be useful to proceed with negotiations and treaties even if the USA (and perhaps other big countries) will not participate in the beginning.

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