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# RISKS FROM MILITARY USES OF NANOTECHNOLOGY - THE NEED FOR TECHNOLOGY ASSESSMENT AND PREVENTIVE CONTROL

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## PROMISES VERSUS RISKS

There is a tendency in the world of high technology to over-advertise conceivable benefits; researchers, funding officers and entrepreneurs understand that investors, politicians and the public have come to expect hype and will react with a yawn to any technical proposal that does not promise to cure cancer, provide limitless energy, prevent terrorism or make stupid people smart. But speak of the unproven hazards posed by future technologies, and one is fast denounced as a doomsayer, a purveyor of science fiction, guilty of exaggeration and extrapolation from dubious premises. In the field of nanotechnology, warnings have been sounded against excessive promises made too soon, lest the public become disillusioned with "nanohype," but the roughest criticism has been dealt to those who not only foretold bountiful results from this new technology, but also warned of grave dangers.[1] Such warnings, many believe, will lead the public to exaggerated fears of the unknown, undercutting support for nanotechnology funding. We believe it is essential to get beyond this battle over atmospherics, and to commence balanced and careful scholarship to assess the actual prospects for good or evil, and to consider what should be done in response to them. We write to address the question of dangers arising from the military use of nanotechnology.[2]

## RISKS OF NANOTECHNOLOGY

Nanotechnology (NT) holds great promises, but also poses grave risks. This applies even when considering only the evolutionary advances expected from current laboratory research and generally-accepted extrapolations of historical trends. It is strongly apparent in the context of visions such as nanoassemblers, self replication, artificial intelligence of human capability and beyond, robotics from nano to macroscale, super-automated production, and nanodevices within the human body, perhaps to eradicate illness, perhaps to interact with the brain. Although there are disputes about the realizibility of these latter concepts, caution demands serious consideration of such prospects unless they can be shown to be physically or technically impossible. To prevent irreversible damages, regulatory measures must be taken in advance of dangerous developments. The risks of NT span a wide range: environmental pollution, increase of inequality, displacement of human workers or even of the human species have been mentioned. Interdisciplinary studies should be undertaken to address these various risks. Here, we want to draw attention to risks linked to military NT activities that could create specific dangers as well as accelerate general developments in such a way that in-depth study and informed decision become more difficult. Military exploitation of NT has barely begun (see Tables 1), but there are strong indications it may expand rapidly,[3] driving and in turn being driven by the technology. Given that the US National Nanotechnology Initiative (NNI) has stimulated similar initiatives in many other countries,[4] the USA may also provide a role model for military R&D there.

**Table 1 Topics of recent military R&D for nanotechnology in the USA. It is probable that other countries have markedly fewer military activities.**

| Some nanoscience and –technology programs funded 1999-2001 by the U.S. Defense Advanced Research Projects Agency (DARPA)[5] | Topic Titles of FY 2001 Defense University Research Initiative on Nanotechnology of U.S. National Nanotechnology Initiative (DURINT)[6] |
|---|---|
| Biological and Amorphous Computing, Nanophase Magnetic Materials, Bio:Info:Physical Systems Interface, Structural Materials and Devices, Microinstruments, Beyond Silicon, Nanoscale/Biomolecular Materials, Molecular-Level Large-Area Printing, Molecular Electronics, Nanotechnology and Crystalline Arrays, Nanoelectric Research | Nanoscale Machines and Motors; Nanostructures for Catalysis; Biomolecular Control of Nanoelectronic and Nanomagnetic Structure Formation; Polymeric Nanocomposites for High-Speed and Space Systems; Nano-System Energetics; Organic Nanophotonics and Nanoelectronics; Characterization of Nanoscale Elements, Devices and Systems; Quantum Computing and Quantum Devices; Synthesis, Purification, and Functionalization of Carbon Nanotubes; Molecular Recognition and Signal Transduction in Bio-molecular Systems; Nanoscale Electronic Devices and Architectures; Synthesis and Modification of Nanostructure Surfaces; Nano-Porous Semiconductors – Matrices, Substrates, and Templates; Magnetic Nanoparticles for Application in Biotechnology; Deformation, Fatigue, and Fracture of Nanostructures and Interfacial Materials |

## POTENTIAL MILITARY NT USES

**Weapons of mass destruction**. Self-replicating nanorobots, aggressively consuming organic material, are perhaps the most oft-mentioned, and perhaps overstated concept, but would probably require an advanced stage of NT development.[7] In the nearer term, NT will provide possibilities in coming decades for more efficient storage, dispersal, and transport of chemical and biological agents into the body and cells of humans, animals, or plants. New agents may remove previous operational difficulties of biological warfare. Advanced capabilities may include the use of genetic markers to target an ethnic group or even a specific individual. New options for nuclear weapons might include NT-based materials extraction and processing, weapons production, and perhaps new types of nuclear weapons. NT manufacturing based on self-replication could produce conventional weapons in such large quantities that they acquire the character of mass-destruction weapons.

**Other weapons**. NT will provide stronger, lighter materials, smaller computer components, new sensor technologies, and - together with and beyond microsystems technologies - many options for miniaturization. NT manufacturing methods may enable mass production of sophisticated expendable systems at low cost. One can foresee greater projectile velocities, stronger light armor, and precision-guidance systems even in small munitions. Low-cost military robots of mini and micro sizes, including biological-technical hybrids, would bring even more radical changes. Such robots would necessarily be capable of autonomous decision and action and could be used for purposes from reconnaissance to attack. In outer space, very small satellites could act as anti-satellite weapons.

**General military applications.** NT will have applications in energy storage and generation, propulsion, displays, sensors and sensor nets, combat information systems, logistics, maintenance, self-repair, smart materials, and more. Some more visionary concepts foresee systems implanted into soldiers' bodies, first for biomedical analysis and reaction, later for information exchange.

**Far-fetched fears? A few selected quotes**

"Third, social and cultural biases to a brain implanted decision tool must be overcome. The Cyber Situation is designed to assist, not control each decision maker. To fully exploit growing technology, cumbersome hardware and software requirements must be reduced to the simplicity and seamlessness of a chip implant."[8]

"Nanotechnology will allow the miniaturisation of sensors and equipment. ... Postulated systems, some further out than 2030, include nano-solar cells offering more efficient electricity generation than present systems, and nano-robots for many potential purposes, but including medical robots that can fight diseases internally in humans, remove and replace defective DNA, and even possibly treat injured personnel. Combined with increases in processing power these systems will have widespread application including in mini-platforms for reconnaissance."[9]

"Beyond technological obstacles, the potential for effective battlefield robots raises a whole series of strategic, operational, and ethical issues, particularly when or if robots change from being lifters to killers. The idea of a killing system without direct human control is frightening. ... Should the United States attempt to control the proliferation of military robotic technology? Is that even feasible since most of the evolution of robotic technology, like information technology in general, will take place in the private sector? Should a fully roboticized force be the ultimate objective?"[10]

## DANGERS AND RISKS OF MILITARY NT USES

When taking a preliminary look at NT under the criteria of preventive arms control (see box), several dangers come to mind, in all three problem areas. These concern:

- arms control agreements (e.g., Biological Weapons Convention through new NT-genetics-based agents, limits on conventional forces by new weapons types outside of treaty definitions) or the international law of warfare (e.g., through introduction of autonomous fighting systems not reliably recognizing non-combatants or combatants hors de combat),
- stability (arms races from technological innovation, pressure for preventive attack and fast action, proliferation of cheap microsystems),
- humans, the environment, or society (microrobots for eavesdropping, crime, and terrorism; uncontrolled self-replication; implanted systems altering human nature).

In the third category dealing with peacetime civilian life, military research and deployment of systems could create "facts" before society is able carry out a thorough debate about the desirability of particular technological developments.

**Preventive arms control - A concept for limiting risks from new military technology** [11]

Criteria of preventive arms control
(1) dangers to arms control agreements and the international law of warfare,
(2) dangers to stability (first strike, arms race, and proliferation)
(3) dangers to humans, environment, or society.
Steps of preventive arms control
(1) prospective scientific analysis of the technology,
(2) prospective analysis of the military-operational aspects,
(3) assessment of both under the criteria,
(4) devising possible limits and verification methods.

**Regulation of Technology - Precedents**

*National level:* Laws and standards for environment, occupational safety, research (e.g., genetics) – with strong inspections

*International level, general:* UN Convention on the Law of the Sea (1982, pollution, exploitation, technology cooperation), UN Framework Convention on Climate Change (1992, reduce greenhouse-gas emissions)

*International level, arms control:* Anti-Ballistic Missile Treaty (1972, no deployment, testing, and development of space-based anti-ballistic missile systems) (now terminated by the USA); Biological and Toxin Weapons Convention (1972, no possession, production, and development of agents for non-peaceful purposes); Blinding Laser Weapons Protocol (1995, bans use of laser weapons designed to produce permanent blindness)

## RECOMMENDATIONS

This purpose of this paper is to raise the international awareness of the dangers that could ensue from military NT activities. Detailed, interdisciplinary studies of these risks are needed, and preventive-arms-control measures should be worked out. Because military and civilian aspects are intertwined, limitations and rules should encompass both, of course duly considering also the beneficial NT uses.

At present we propose the following general guidelines:

- No circumvention of existing treaties.
- A comprehensive ban on space weapons.
- Prohibition of autonomous "killer robots."
- Specific restrictions on small autonomous systems.

As first steps, we suggest:

- Measures to prevent production or release of systems capable of self-replication in the wild should be concluded internationally, binding both the civilian and military sectors.[12]
- The nanotechnology initiatives of various nations should work together to build confidence and common purpose, and to address concerns such as arms control, safety protocols, and social implications.[13]

In the long run, containing the risks of the new powerful technologies - genetic engineering, pervasive computer networks, micro-systems, and nanotechnology - will probably require fundamental changes in the international system, particularly strengthening of law and political institutions, including international criminal law, and reorienting of the military mission from warfighting to organizing cooperative security.

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1 K.E. Drexler, *Engines of Creation* (New York: Anchor Press, 1986): ch. 11, 12; M. A. Gubrud, Nanotechnology and International Security, *Fifth Foresight Conference on Molecular Nanotechnology,* Nov. 1997, http://www.foresight.org/Conferences/MNT05/Papers/Gubrud/index.html; Bill Joy, Why the Future Doesn't Need Us, Wired **8** no. 4, April 2000 (http://www.wired.com/wired/archive/8.04/joy.html). For one such criticism, see Tolles (note 2).

2 This is an especially difficult issue because "hawk vs. dove" perceptions tend to overshadow the debate. Thus, immediate reactions before careful scientific inquiry should not come as a surprise. In the Proceedings of the first NSF Workshop on Societal Implications of Nanotechnology one of us [M.A.G.] was cited as an exponent of "bizarre predictions," in particular "the concept of weapons that 'fire themselves' when an enemy is detected…" The author, W. M. Tolles of the Naval Research Laboratory (Ret.), asserts that "under all circumstances, decisions in the U.S. have avoided consideration of any such weapons." (W. M. Tolles, National Security Aspects of Nanotechnology, in M. C. Roco, W. S. Bainbridge, eds., *Societal Implications of Nanotechnology* (Dordrecht etc.: Kluwer 2001, also via http://www.nano.gov). In reply one could point to mines and target-recognizing terminal guidance systems, but the real issue here is that of robots that may one day employ more sophisticated forms of artificial intelligence to autonomously make life-and-death decisions in combat. As discussed in a recent perceptive essay in the US Army War College Quarterly, the use of such technologies is likely to be compelled by "military systems (including weapons) now on the horizon [that] will be too fast, too small, too numerous, and will create an environment too complex for humans to direct." (T. K. Adams, Future Warfare and the Decline of Human Decisionmaking, *Parameters* **31**, no. 4 (Winter 2001), also http://carlisle-www.army.mil/usawc/Parameters/01winter/adams.htm). See also M. C. Libicki, *The Mesh and the Net: Speculations on Armed Conflict in a Time of Free Silicon* (Washington: National Defense University, Institute for National Strategic Studies, 1994); S. Metz, The Next Twist of the RMA, *Parameters* **30**, no. 3 (Autumn 2000), also http://carlisle-www. army.mil/usawc/Parameters/00autumn/metz.htm.

3 Within the U.S. National Nanotechnology Initiative, $180 million of the FY 2002 $604 million will be spent for defense: M.C. Roco, Research and Development FY 2002 - National Nanotechnology Investment in the FY 2002 Budget Request by the President, http://nano.gov/2002budget.html

[4] M. C. Roco, International strategy for nanotechnology research and development, Journal of Nanoparticle Research **3**: 353-360, 2001

[5] Based on a perusal of Department of Defense FY 2001 Budget Estimates, February 2000, RDTE Defense-Wide, vol. 1, DARPA - Unclassified (http://www.darpa.mil/body/pdf/DARPAFY2001BudgetEstimates.pdf)

[6] DURINT 2001 Topics, http://www.onr.navy.mil/sci_tech/special/durint/DURINTtopics.htm

[7] Assuming a similar level of development for defensive preparations, such threats may turn out to be counterable if they are feasible, despite popular perceptions of nanotechnology as likely to unleash a "grey goo" plague. See R. Freitas, "Some Limits to Global Ecophagy by Biovorous Nanoreplicators, with public policy recommendations," http://www.foresight.org/NanoRev/Ecophagy.html; see also ref. 12.

[8] W. B. Osborne et al., Information Operations: A New War-Fighting Capability, A Research Paper Presented to Air Force 2025, Air University, Aug. 1966 (p. 56) (http://www.au.af.mil/au/2025/volume3/chap03/vol3ch02.pdf)

[9] UK Ministry of Defence, The Future Strategic Context for Defence, Febr. 2001 (http://www.mod.uk/index.php3?page=2449)

[10] Metz (note 2)

[11] J. Altmann, Military Uses of Microsystem Technologies - Dangers and Preventive Arms Control, Münster: agenda, 2001, and references given there

[12] The Guidelines of the Foresight Institute may serve as a starting point (Foresight Guidelines on Molecular Nanotechnology, Revised Draft Version 3.7: June 4, 2000, http://www.foresight.org/guidelines/current.html). In particular, their exclusion of agreements on the military sector should be amended.

[13] The various efforts at international outreach and cooperation carried out by the US NNI are to be commended here.