Revolutionary Technologies and International Security

Jürgen Altmann

Experimentelle Physik III
Technische Universität Dortmund

Dortmund, Germany

ISODARCO XXVI Winter Course

Andalo, Italy

6-12 January 2013

Projects on military applications of nanotechnology and on armed uninhabited vehicles funded by German Foundation for Peace Research DSF

Here, then, is the problem which we present to you, stark and dreadful and inescapable: Shall we put an end to the human race; or shall mankind renounce war?

Russell-Einstein Manifesto, 9 July 1955, signed by 11 scientists
(referring to nuclear weapons)

New revolutionary technologies: additional arguments and chances?

Overview

1. Technological Revolutions
2. Revolutionary Technologies in the Military
3. Arms Limitation: Verification Problem
4. Regulation of Dangerous Technologies – Civilian Realm
5. Regulation of Military Technology in the International System
6. Requirements for Verification of Limits on New Technologies
7. Two Alternatives if Not Acceptable
8. Conclusion

1. Technological Revolutions

Technical revolutions ⇔ production types ⇔ social order

Coal, steam, steel ⇔ capitalism

Information technology, Internet ⇔ globalisation

Revolutions in military technology ⇔ international system

Fire arms: victories over societies without them, colonialism ...

Nuclear weapons: avoid wars between great powers, arms control, UNO

What will happen with the coming technologies?

Technical Revolutions Today and Tomorrow

Information and communication technology

Biotechnology, genetic engineering, proteomics, ...

Robotics, artificial intelligence

Cognitive science, neuroscience/-technology

Nanotechnology

- Converging technologies

Civil Society:

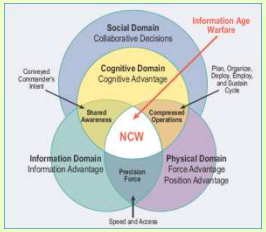
Health? Environment? Jobs? Privacy? Just distribution of chances, goods? Image of human?

Hopefully manageable – but: military uses

2. Revolutionary Technologies in the Military

TODAY: precision/"smart" weapons, computers on the battlefield, uninhabited vehicles ...

US Air Force



US Air Force

TOMORROW:

3-D printers

Small sensor systems

Small missiles and other small weapons

Autonomous combat systems

Small robots, swarms

Implants and other body manipulation

Selective chemical/biological weapons

Synthetic biology

Cyber attacks

...

3-D printers

Wired

MakerBot Commandos: Special Ops Seek 3D Printer

By Adam Rawnsley August 12, 2011 | 12:01 pm | Categories: Gadgets and Gear

Follow @arawnsley

Darpa, announced they'd like to get into the desktop manufacturing business. Their plan was to have swarms of mini robots use 3D printing technology to stamp out multifunctional, metamorphic and programmable materials.

(Fig. from http://www.dimensionprinting.com/3d-printers/printing-productspecs1200series.aspx)

Dimension 3 D Printers

Gun Lobby Loves 3D-Printed Weapons

By Robert Beckhusen August 10, 2012 | 6:30 am | Categories: Gadgets and Gear

Follow @rbeckhusen

(Fig. from http://www.wired.com/dangerroom/2012/08/3d-weapons)

Pentagon's Plans For 3-D Printers: Mobile Labs, Bomb Sniffers and Prototype Limbs

By Robert Beckhusen October 8, 2012 | 3:26 pm | Categories: Gadgets and Gear

Follow @rbeckhusen

Guslick/Wired

For the time being thermoplastics – later maybe ceramics, metals

Small Sensors

Smart dust

(Figure from https://ipvszope.informatik.uni-stuttgart.de/ipvs/abteilungen/bv/abteilung/mitarbeiter/Serge.Kernbach/Serge.Kernbach_infos/index)

S. Kernbach Univ. Stuttgart

Future: sub-mm size

Small missiles and other small weapons

TiGER MBDA
Tactical Grenade Extended Range

Range 3 km

Warhead 0.5 kg

(Figure from www.mbdainc.com/downloads/tiger-data.pdf)

MBDA

Switchblade AV Inc.

Range 10 km

Endurance 10 min.

2.5 kg w. launcher, bag

(Figure from http://www.avinc.com/downloads/Switchblade_Datasheet_032712.pdf)

AV Inc.

Mini-Spike Anti-Personnel Guided Weapon Rafael

Range 1.2 km

4 kg

(Figure from http://defense-update.com/photos/mini_spike.html)

Eshel, Defense Update

Future: micro missiles against aircraft

Micro Air Vehicles

Nano Hummingbird

Febr. 2011

Figure from http://www.avinc.com/nano

AeroVironment
DARPA Contract

Wing Span 16 cm
Total mass 19 g
Propulsion electrical

Payload: Video camera with transmitter

Endurance 11 minutes

AeroVironment

AFRL Video 2009

AFRL 2009

Video 1:51-3:11
From
http://www.youtube.com/watch?v=_5YkQ9w3PJ4

Bio-technical Hybrids

Talwar et al. 2002

Rat navigation guided by remote control

Free animals can be 'virtually' trained by microstimulating key areas of their brains.

Procedures used to train laboratory animals often incorporate operant learning[1] paradigms in which the animals are taught to produce particular responses to external cues (such as aural tones) in order to obtain rewards (such as food). Here we show that by removing the physical contraints associated with the delivery of cues and rewards, learning paradigms based on brain microstimulation enable conditioning approaches to be used that help to transcend traditional boundaries in animal learning. We have used this paradigm to develop a behavioural model in which an experimenter can guide distant animals in a way similar to that used to control 'intelligent' robots.

Depending on the site of brain stimulation, an electrical stimulus can act as a cue or a reward[2–4]. Studies of these phenomena have generally been concerned with functional mechanisms of the nervous sytem[5], and little thought has been given to the potential of behavioural paradigms constructed wholly around such focal brain stimulations. We used stimulation of the somatosensory cortical (SI) and medial forebrain bundle (MFB)[3] as 'virtual' cues and rewards, respectively, delivered to freely

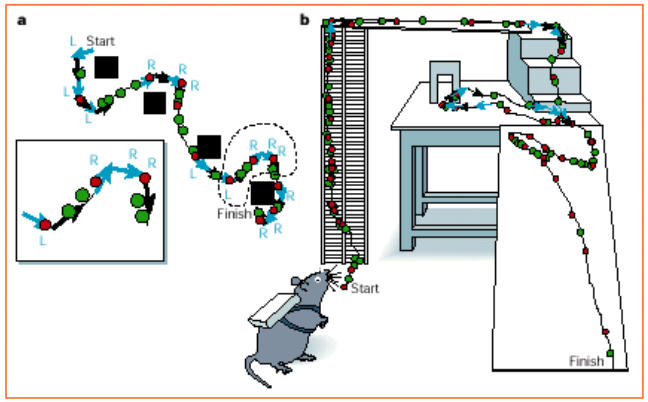


Figure 1 Examples of guided rat navigation using brain microstimulation. Sketches are constructed from digitized video recordings. Red dots indicate rat head positions at 1-s intervals; green dots indicate positions at which reward stimulations were administered to the medial forebrain bundle (MFB); blue arrows indicate positions at which right (R) and left (L) directional cues were issued; black arrows indicate positions 0.5 s after directional commands. **a,** Route followed by a rat guided through a slalom course. Inset, detail of the events that took place inside the dashed enclosure. **b,** Route taken by a rat guided over a three-dimensional obstacle course. The animal was instructed to climb a vertical ladder, cross a narrow ledge, descend a flight of steps, pass through a hoop and descend a steep (70°) ramp. Two rounds of high-density MFB stimulation were required to guide the rat successfully down the ramp, demonstrating the motivational qualities of MFB stimulation.

(Figure from http://spectrum.ieee.org/robotics/military-robots/cyborg-moth-gets-a-new-radio/0)

CYBER-MOTH: Electrodes and a control chip are inserted into a moth during its pupal stage. When the moth emerges the electrodes stimulate its muscles to control its flight.

Funding: DARPA

www.renachip.org

Bozkurt, Boyce Thompson Institute

Future: intelligence, anti-personnel

Selective Chemical or Biological Agents/Weapons

Medical nanobiotechnology:

- **capsules for safer enclosure and delayed release of agents**
- **active groups for bonding to specific targets in organs or cells**
- **mechanisms for easier entry into the body or cells, in particular in the brain**
- **mechanisms for selective reaction with specific gene patterns or proteins**
- **mechanisms to overcome the immune reaction of the target organism**

Could all be used for hostile purposes

Sophisticated mechanisms: limit to specific groups or even an individual, affect special organ or brain centre

Example of civilian research

Peng et al. 2007

Nanoparticles of C32 polymer

functionalised with DNA to express diphteria toxin A – activation only in presence of a prostate-specific modified human PSA promoter (PSE-BC)

injected into normal mice prostates and prostate tumors

Much more DNA activation with nanoparticles than with naked DNA

Significant cell death in prostates and tumors – little damage to surrounding tissue

Synthetic Biology

2002: Genome of polio virus synthesised, virus self-assembled

2005: Virus of Spanish influenza of 1918 reconstructed

Put together DNA for new biological systems to produce intended products/actions

BioBricks – standard DNA sequences for certain functions

DNA synthesizers:

Providers run checks on customer sequences

Not if one‘s own synthesizer

Figure from http://www.ncyu.edu.tw/bioagriculture_eng/content.aspx?site_content_sn=22844

http://www.ncyu.edu.tw

Do It Yourself Biology

Hobbyists

(Figure from
http://diybio.org)

(Figure from
http://diybio.org/2012/06/11
/dremelfuge-classic/)

www.DIYBio.org

Sufficient concern that FBI has hired a biochemist for contacts to the do-it-yourself-biology community

Cyber Attacks

Stuxnet

- **Highly sophisticated**
- **Spread via Windows**
- **Targets Siemens SCADA systems for industrial control**
- **Mostly against Iran and its uranium-enrichment plant**

Cyber Commands founded in many countries

Defence + offence

USAF/warnewsupdate

Utopian Scenarios

Self replicating nano-robots?

With Evolution?

Strong artificial intelligence?

Too speculative at the moment

- but if feasible, unprecedented dangers for humankind

Use by Terrorists: Can be Limited by Agreements Among States

Much of this can only be developed by states

would be available later also for less capable weapon producers

would proliferate via white, grey and black markets

would be available for terrorist attacks, too

Terrorists and other criminals are limited in what they can develop:

- **Limited funds**
- **Limited number of scientists/engineers**
- **Limited opportunities/areas for testing**
- **Under pressure of prosecution**

Terrorists cannot be parties to limitation agreements

But limitation among states would go a long way in preventing access by terrorists to sophisticated military systems

On the Other Hand: Production by Small Groups/Individuals

Several technologies will allow manufacture in cheap, small equipment with universal capabilities

DNA synthesizers

3-D printers

Controlled by software

Need: raw materials

Available due to civilian uses

Main hurdle then: software for destructive objects

DNA synthesis firms: scan customer orders for dangerous sequences

Does not work if synthesis is done in one's own synthesizer

3. Arms Limitation: Verification Problem

Agreed arms control: verification dilemma

if no reliable verification

⇒ suspicion of circumvention by others

⇒ motive for one's own circumvention

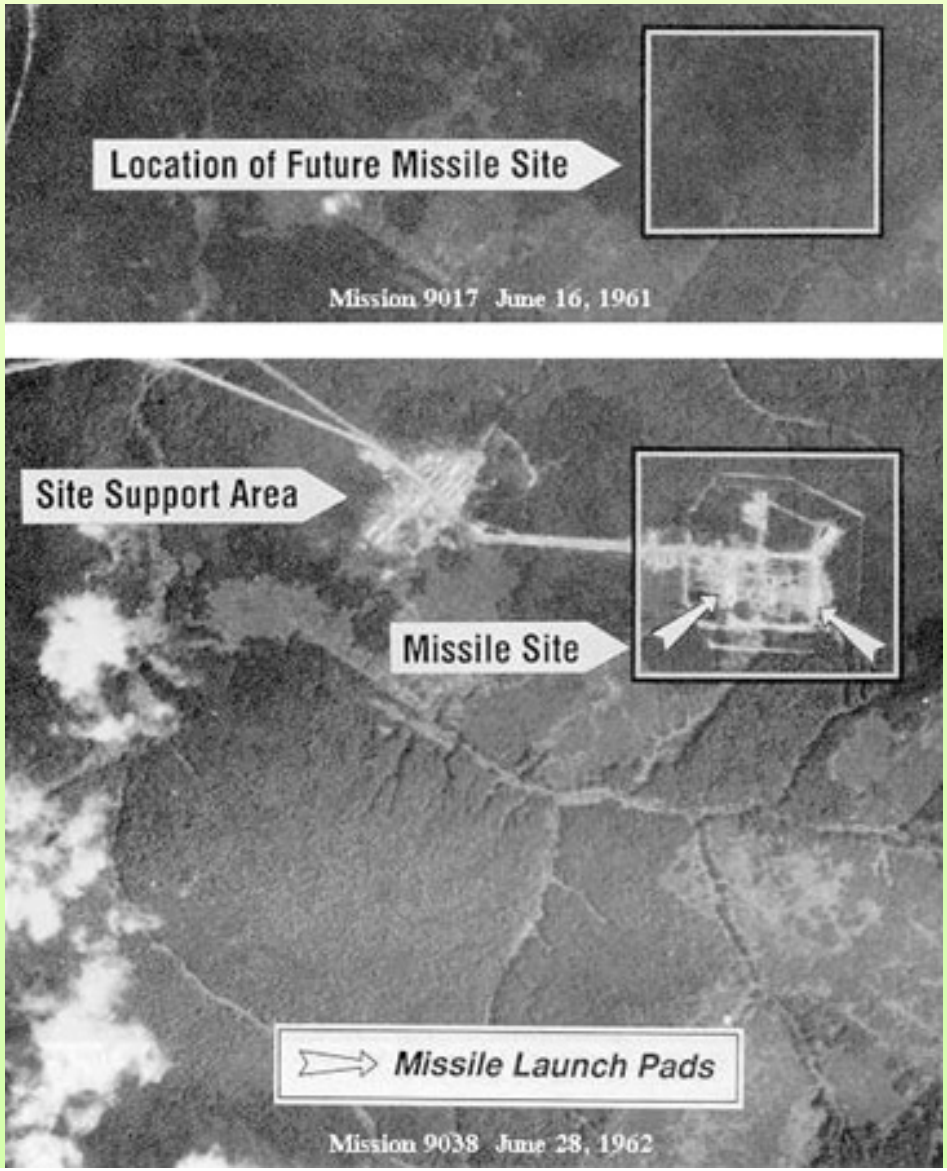
⇒ reliable ("adequate") verification needed, transparency

Conflict with military secrecy, in part required for very task of armed forces (victory in armed conflict):
Fear of revealing technical properties, weak points, structures, plans, motivation, ...
- could be used for (surprise) attacks

Solve by creative mix of limited transparency and procedures

Traditional arms control (nuclear-weapon carriers, nuclear explosions etc.):

large objects/events, often detectable from outside by "national technical means of verification"



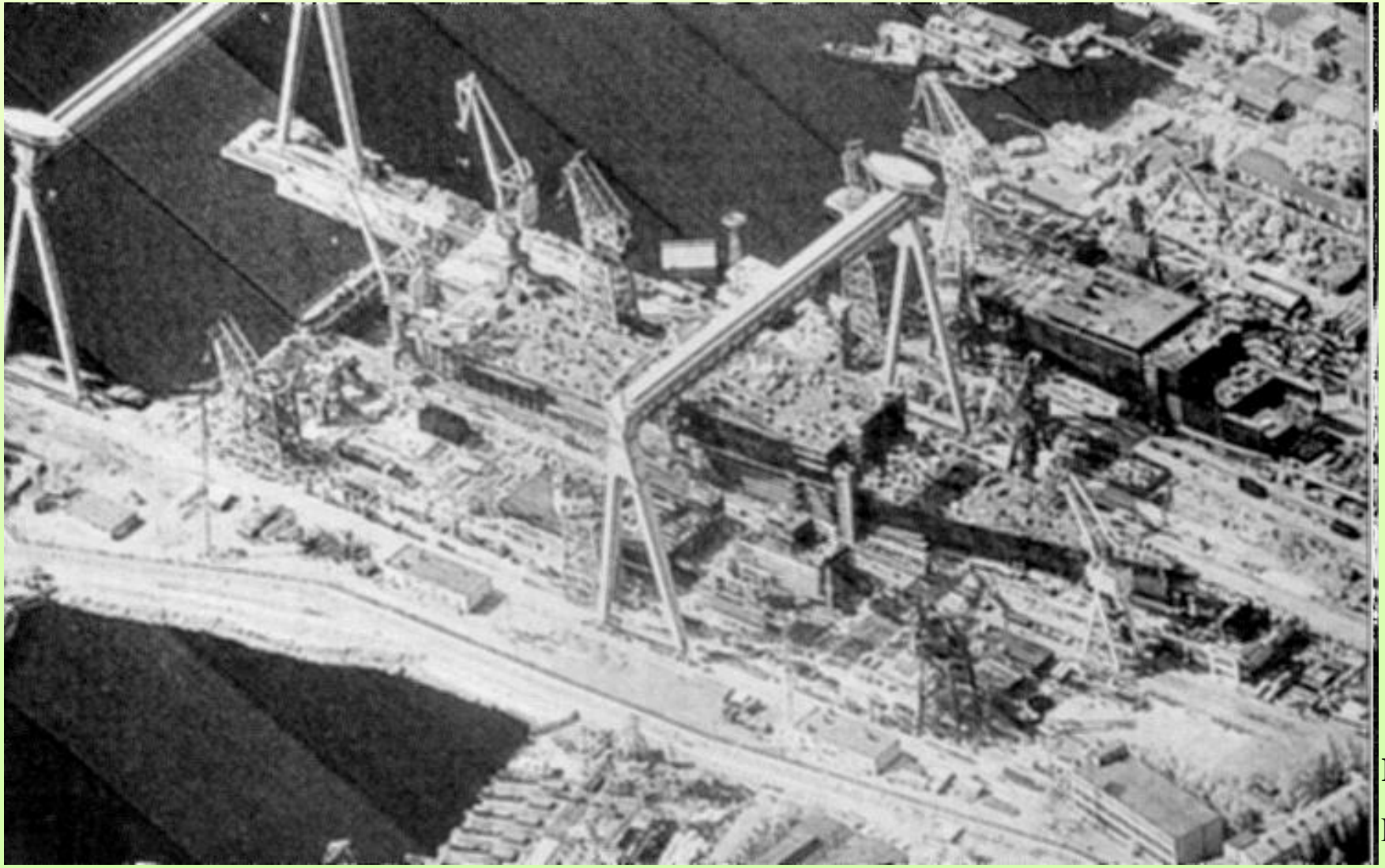
Two U.S. Corona reconnaissance satellite images made a year apart—in mid-1961 (top) and mid-1962 (bottom)—revealing the construction of a new Soviet SS-7 Saddler (R-16) intercontinental ballistic missile site. Located at Yur'ya, Russia, the site was the first Soviet ICBM complex to be identified in Corona images.

National Reconaissance Office

Military shipyard in Nikolayev, Ukraine

Intelligence-service photo of 1984

Building of the aircraft carrier Kusnetsov



KH-11

FAS

Limits on smaller systems: more intrusive verification needed

on-site inspections, in barracks, laboratories, firms;

sample taking and analysis, ...

1987 *Intermediate Range Nuclear Force* (INF) *Treaty*

Data exchange; on-site inspections, even permanent presence at missile productions plants, various types of equipment

(Figure from vmpf.net)

vpmf.net

1990 *Conventional Armed Forces in Europe* (CFE) *Treaty*:

Annual data exchange; on-site inspections with some equipment at selected sites, short-term notice which

1991 *Strategic Arms Reduction Treaty* (START I):

Data exchange; on-site inspections with permanent presence at missile production plants, long lists of equipment for inspections, perimeter, portals

1993 *Chemical Weapons Convention*:

Organization for the Prohibition of Chemical Weapons (The Hague, NL)

Verification Annex included

Declarations, on-site inspections: destruction, storage sites, chemical industry; sample taking and analysis

OPCW

1972 *Biological Weapons Convention*:

No verification mechanism – not deemed necessary 1972 because of risk of infecting one's own troops and population

Efforts for a compliance and verification protocol:

1992-1993 meetings of government experts

1994 mandate for Ad Hoc Group

1995-2001 negotiations, rolling text prepared, still many brackets (un-agreed parts)

2001 US withdrew – problems: inspectors in biodefence laboratories, in life-science laboratories of private companies

1996 *Comprehensive Test Ban Treaty* (CTBT):

CTBT Organization (Vienna, AU)

International Monitoring System worldwide (seismological, radionuclide, hydroacoustic, infrasound); data to International Data Centre (Vienna)

On-site inspections to area of event (after entry into force), various sensor types and other equipment

(Figure from http://www.ctbto.org/verification-regime/building-theinternational-monitoring-system/1994-1996-reaching-critical-mass/)

CTBTO

1997 *Anti-Personal Mine Convention*:

Transparency measures; clarification via UN Secretary General; fact-finding mission by experts

2008 *Convention on Cluster Munitions*:
Transparency measures; clarification via UN Secretary General

Verification is Getting Ever More Difficult

Dual use **- similar processes/technologies for civil as well as military application**

More broadly available, cheap, small**: today PC with internet connection, tomorrow 3-D printers, DNA synthesizers, fermenters, microreactors**

Robotic systems**: fast/easily reprogrammable, modules exchangeable**

If *implants* and other *body manipulation* widely used: military application barely separable

Cyber attacks**: attribution difficult**

Also *small countries* can use high technology (militarily)

Non-state actors **(small groups, individuals) can use enabling technologies for nefarious purposes**

Preparations and production could be done in *small, inconspicuous facilities*

4. Regulation of Dangerous Technology – Civilian Realm

- Within (Democratic) States

Misuse prevented / minimised by laws, other regulation

**Monopoly of legitimate violence rests with state,
state has power and means/personnel to enforce compliance with the law**

Perpetrators are being prosecuted, put to jail etc.

Far-reaching inspection rights of state as routine procedures, at (urgent) suspicion of violation: workplace protection, environmental protection, accounting, exports, ...

Broadly accepted - safety and security of citizens and society require rules, checking of compliance and criminal prosecution

With revolutionary technologies:

State regulation approaches its limits if liberties are to be preserved

Regulation of Dangerous Technology – Civilian Realm
- In the International System

By standards, conventions

(Most) states co-operate, guarantee compliance by entities in their jurisdiction

Some problems from economic competition

Military uses:

Fundamentally different

5. Regulation of Military Technology in the International System

Military Use of New Technology

Potential for selective or massive destruction: make usable as fast as possible

Research of new possibilities, if suitable, develop military systems

- protected and ordered by the state, with its resources and much personnel

Justified by highest national interests

Task of armed forces: in armed conflict prevail by selective or massive destruction

Central means of prevailing: new technology

Task of armed forces $\Rightarrow$ tendency towards transcending civil boundaries, secrecy

Military uses: not often looked at in technology assessment

- **special conditions**
- **intertwined with international security, in particular security dilemma**

Security Dilemma and Arms Control

International system: anarchy – no overarching authority guarantees security

No monopoly of legitimate violence

Each state attempts to achieve security by threat of armed forces

- in this process increases threat to others

- overall result: security of all decreases

One way out:

voluntary mutual limitation of armed forces (arms control)

- but friction with goal of victory should war nevertheless break out

⇒ conceptually different framework for technology assessment and ensuing regulation
- international agreements
- voluntary
- combat power
- secrecy

Regulation of Dangerous Military Uses of (New) Technology

Possible by preventive arms control

Arms control: Potential opponent states limit their military power by agreement

Usually requires adequate verification of compliance

Can be

- **Quantitative (numbers of carriers, warheads etc.) or**
- **Qualitative (types, properties of weapons)**

***Preventive arms control*: qualitative arms control applied to future**

Ban/limit military usable technology or weapons systems *before* acquisition

Precedents

Partial Test Ban 1963 → Comprehensive Test Ban 1996

Non-Proliferation Treaty 1968

ABM Treaty 1972-2002

Biological Weapons Convention 1972

Chemical Weapons Convention 1993

Blinding Laser Weapons Protocol 1995

Most: prohibition already of development and testing

6. Requirements for Verification of Limits on New Technologies

Proposals for limits on armed UVs (made by J.A./ICRAC)	*Verifiable* (e.g. by on-site inspection)
No armed uninhabited vehicles (UVs)	Yes
No autonomous attack by armed UVs	No
Limits on teleoperated armed UVs	Yes
Proposals for limits on small systems (made by J.A. for nanotechnology)	
No sensor systems below 3-5 cm	Yes
No missiles below 0.2-0.5 m	Yes
No mobile systems below 0.2-0.5 m	Yes

On-site inspections to military installations including testing/training sites, later with magnifying equipment

Traditional verified arms control still possible (if political will)

Increasing Requirements for Verification

No development, testing, production of biological weapons in traditional institutions

- Inspections in research, development, testing institutions, military and industry with sample-taking and analysis

No development, testing, production of new selective biochemical agents in cheap, small-scale equipment

- Inspections anywhere

No hand-portable 3-D printers used for production of small weapons

- Inspections anywhere

Increasing Requirements for Verification

Quantitative limits on armed minirobots (say, USA/RUS/China each 15,000 between 2 cm and 20 cm)

- Inspections anywhere, but numerical limit extremely difficult to check

Quantitative limits on armed microrobots (say, USA/RUS/China each 150,000 between 0.5 mm and 2 cm)

- Inspections anywhere, but numerical limit extremely difficult to check

Ban/limit on offensive cyber operations

- Checks on programming and software in the cyber-warfare units

Verification Possible/Acceptable?

International limits on military uses of revolutionary technologies will need very intrusive verification

Anytime anywhere in nearly all countries

But still armed forces prepare for victory

One component: secrecy (about technologies, specifications, software, …)

Will military preparations with the required degree of secrecy still be deemed possible under anytime-anywhere inspections with intensive analyses?

Will armed forces and states accept such intrusive verification?

Plus: fear of industrial espionage, of intrusion into privacy

If yes: good, conclude these agreements

But improbable

7. Two Alternatives if Not Acceptable

Alternative 1: Leave international system as it is

Unregulated arms races (global, regional)

Increasing military threats, marked instability

- **Cyber attacks attributed to wrong originator, automated "response", escalation to real-world attacks**
- **Swarms of mini-UAVs disrupting nuclear-strategic installations**
- **Very small satellites attacking important civilian and military satellites**
- **Pre-deployed micro-robots inside military systems, ready to strike any time**
- **…**

AFRL

Increasing terrorist threats

– **Assassinations of politicians by small, target-seeking missiles pulled out from lady's handbags**

– **"Molecular hackers" distributing unknown infectious agents - general or selective**

– **...**

Alternative 2: Organisation of global security in another way

Similar as within states

- **monopoly of legitimate violence resting with (democratised) UN, international criminal law with right to act within states, ...**
- **voluntarily reduced sovereignty**

Idea of dominant world authority is old

World Federalists (1940s)

Baruch plan for nuclear weapons (1946)

World domestic politics (v. Weizsäcker 1960s etc.)

…

Often seen as idealistic, illusory

However: first trends exist already (UN, EU, International Tribunals, ...)

Additional factors: economic interdependence, globalisation, Internet …
⇒ large-scale war less probable, nothing to gain, much to lose

8. Conclusion

Extreme dangers from military development and uses of revolutionary technologies, starting in maybe 2 decades

Traditional arms control could become impossible because verification would be too intrusive for the military, maybe also for industry and society at large

Softer solutions to prevent malign/hostile uses (such as codes of conduct for scientists/engineers) will become more important – but will not suffice to prevent military innovation, due to the security dilemma

Understanding this may become an important argument for fundamental re-thinking about how security should be provided in the international system.

Learning from catastrophes: hopefully not – or at least not from big ones

Working this argumentation out in detail: important topic for interdisciplinary research

References

J. Altmann, Military Nanotechnology: Potential Applications and Preventive Arms Control, London etc: Routledge, 2006 (Russian version: Moscow: Tekhnosphera, 2006)
J. Altmann, Nanotechnology and Preventive Arms Control, DSF Forschung no. 3, Osnabrück: DSF, 2005 (http://www.bundesstiftung-friedensforschung.de/pdf-docs/berichtaltmann.pdf)
J. Altmann, Preventive Arms Control for Uninhabited Military Vehicles, in R. Capurro, M. Nagenborg (eds.), Ethics and Robotics, Heidelberg: AKA, 2009, http://e3.physik.tu-dortmund.de/P&D/Pubs/0909_Ethics_and_Robotics_Altmann.pdf
Robert Beckhusen, Gun Lobby Loves 3D-Printed Weapons, Wired, August 10, 2012, http://www.wired.com/dangerroom/2012/08/3d-weapons
Robert Beckhusen, Pentagon's Plans For 3-D Printers: Mobile Labs, Bomb Sniffers and Prototype Limbs, Wired, October 8, 2012, http://www.wired.com/dangerroom/2012/10/printers/ (12 Oct. 2012)
Adam Rawnsley, MakerBot Commandos: Special Ops Seek 3D Printer, http://www.wired.com/dangerroom/2011/08/special-ops-meets-makerbot-commandos-want-3d-printer
Peng W, Anderson DG, Bao Y, Padera RF Jr, Langer R, Sawicki JA, Nanoparticulate delivery of suicide DNA to murine prostate and prostate tumors, Prostate 67(8): 855-863, 1 June 2007
Cello J, Paul AV, Wimmer E. Chemical synthesis of poliovirus cDNA: Generation of infectious virus in the absence of natural template. Science 2002 Aug 9; 297(5583): 1016-1018
Tumpey TM, Basler CF, Aguilar PV, Zeng H, Solorzano A, Swayne DE, Cox NJ, Katz JM, Taubenberger JK, Palese P, Garcia-Sastre A, Characterization of the reconstructed 1918 Spanish influenza pandemic virus, Science. 2005 Oct 7;310(5745):77-80