



Committee Reports

SCIENCE AND TECHNOLOGY

SPECIAL REPORT

EMERGING TECHNOLOGIES AND THEIR IMPACT ON ARMS CONTROL AND NON-PROLIFERATION

Lothar Ibrügger (Germany)
Special Rapporteur

International Secretariat
October 2001

CONTENTS

- I. [INTRODUCTION](#)
- II. [REVOLUTIONISING THE MILITARY](#)
- III. [THE TECHNOLOGIES](#)
 - A. NON-LETHAL WEAPONS
 - 1. Non-lethal?
 - B. WEAPONS IN SPACE
 - 1. The US programme
 - 2. International reactions
 - 3. International legal aspects
 - C. NANOTECHNOLOGIES
- IV. [CONCLUSIONS](#)

The Rapporteur would like to thank Lara Nettelfield for her assistance in preparing this Report.

I. INTRODUCTION

1. The past decade has witnessed remarkable advances in weapons technologies, predominantly in the United States, but increasingly in other parts of the world, notably Western Europe. Attention to these technologies has tended to focus upon their development, deployment and possible applications on the battlefield. However, their potentially profound implications for arms control or other international legislation have received far less attention.
2. Some of these emerging technologies seem to be only within the realm of science fiction novels: tiny robots, nanotechnologies, non-lethal weapons, stink bombs, super-adhesives, pepper sprays. Yet, these highly sophisticated and seemingly futuristic technologies are already being utilised in certain areas or are considered a viable

option for defence ministry planning departments, not to mention in some local police departments. As technological developments alter the way that we deal with macro-societal problems such as war, social unrest and civil disobedience, it is important to understand 1) what technologies are being developed and why; 2) how they will possibly be used in the future; 3) how these technologies are governed by international law and treaties; 4) what their potential misapplications/misuses are; 5) what the implications are for future arms control regimes. The purpose of this report is to discuss briefly these issues, to provide the reader with a general overview of this topic, so as to offer a base for future discussions. In the Rapporteur's view, it is imperative that these developments do not go unnoticed.

3. It is well known that the quality and quantity of interventions in both conflict and post-conflict situations have changed in the post-cold war environment. One of the central concerns of foreign ministries has been a desire for states to limit the number of casualties sustained in any intervention, lest there be an immediate withdrawal of public support for an operation. Simultaneously, the civilian dimension of these conflicts - the need to protect large movements of refugee populations and avoid civilian casualties, as in Kosovo, or the need to control populations, as witnessed at the G8 summit in Genoa - provide operations planners with new problems to be confronted. Some common questions are: how can a military operation be conducted in a manner that limits the number of civilian casualties? How can populations be controlled in a way that limits injuries? Thus, a sort of paradox emerges: a desire to limit casualties while the new technologies being employed raise questions about their legality under international law because of their potentially harmful effects.
4. New technologies provide a different set of options for these types of problems faced by governments. And because the nature of operations has changed, there has been considerable convergence between the technologies employed by the military and the police. It is important to explore exactly what types of technologies are in development, to consider how they may be used in the future. Only once these issues have been fully considered and scenarios for future use and development fully explored can a discussion about new arms control regimes be started.

II. REVOLUTIONISING THE MILITARY

5. The leap forward in weapons technology is often seen as constituting a Revolution in Military Affairs (RMA). An RMA has been described as "a major change in the nature of warfare brought about by the innovative application of new technologies which, combined with dramatic changes in military doctrine and

- operational and organisational concepts, fundamentally alters the character and conduct of military operations".
6. There have been many previous instances of such revolutions. Some of those most frequently cited include the introduction of gunpowder and the development of the steam engine, the submarine, the internal combustion engine, the aeroplane and the atom bomb. These technologies alone do not constitute an RMA, but their innovative application in the conduct of warfare is said to have constituted a revolution, as opposed to an evolution, in military affairs. Two criteria must, therefore, be met in order to establish an RMA: firstly, that a modern technology exists, and secondly, that its innovative application bring about changes in the very conduct of warfare.
 7. Proponents of the current RMA believe the development of Information Technology (IT) and the increased adoption of joint and combined military doctrine (designed to maximise the advantages of the available technology) are the driving factors behind the present RMA. The creation of new operational concepts is particularly significant. The United States has been the forerunner in this development, publishing in 1996 a document entitled "Joint Vision 2010" (JV2010). JV2010 outlines two key concepts relating to the conduct of warfare by the United States armed forces in the 21st century: the importance of technological superiority and the increased use of joint operations.
 8. Other United States military publications that develop this concept include the Concept for Future Joint Operations (CFJO), Army Vision 2010 (AV2010) and the Army After Next (AAN). CFJO essentially builds upon JV2010, detailing follow-on assessments for future joint operations. AV2010, in the same vein, identifies the patterns of operations and technologies that the US Army will need in the 21st century to convert its joint vision into reality. AAN looks thirty years further ahead, building upon the ideas of AV2010. Other nations are reaching similar conclusions in the field of military doctrine. The United Kingdom, in its Strategic Defence Review (SDR) of 1998, highlighted the importance of "jointery" or joint doctrine, and is, among other things, developing Joint Force 2000 intended to combine Royal Navy and Royal Air Force fixed-wing aircraft.
 9. The existence of a capability or technology gap between the United States and its European Allies has been well documented. The technology gap refers to the disparity between the United States' application of "high" military technologies such as stealth technology, long-range precision-guided munitions and uninhabited aerial/combat vehicles, compared to the European Allies' more lethargic up-take of new technology. The presence of this gap would seem automatically to imply that the US will take the lead on all developments of these new technologies.
 10. However, as a result of the previously-mentioned convergence between technologies employed by the military and the police, it is possible that domestic developments in some European countries could impact the technologies employed in military operations

abroad, ultimately influencing choices made, for instance, in future military operations undertaken by the European Union under the guise of its planned Rapid Reaction Force (RRF). And while large research budgets will be needed to develop sophisticated technologies like nanotechnologies, some of the new tools being developed today are relatively inexpensive. The United States is now clearly the leader in the revolution influencing technologies employed in military affairs. However, new technologies may offer potential opportunities for European Allies to take the lead in some types of weaponry. Thus, Europeans need to think more creatively about the possible implications of the capabilities gap on technology development.

11. At the same time, the technology gap between the United States and Europe may have serious political and strategic consequences in the transatlantic relations context. Not only because of its possible consequences - as your Rapporteur indicated in his 1998 report on RMA - on interoperability in the conduct of joint allied operations, but also in consideration of the direction taken by the Bush administration on US foreign policy. Recent decisions by the United States to withdraw from or reject international treaties and agreements (the ABM treaty, the Biological Weapons Convention Protocol, the Kyoto Protocol, and a small weapons control agreement) indicate, as William Pfaff has recently written in the *International Herald Tribune*, that "an ideological hostility to international law, evident for some time among members of what used to be called the extreme right, (...) under Mr. Bush's presidency has moved into the Republican mainstream." The association of this kind of political attitude toward multilateral security agreements and overwhelming US technological and military superiority is something that should be at the centre of the transatlantic debate in the very near future.

III. THE TECHNOLOGIES

12. The emerging technologies themselves stem from a wide array of disciplines. Some of these are already at the development stage and others are already being utilised even though they might sound futuristic. For instance, the American-Israeli Tactical High Energy Laser (THEL) effectively intercepted a test missile in June 2000, a test that was successfully repeated in September 2000. This system will shortly be deployed by Israel where it is intended to negate the threat posed by Katyusha rockets often fired from the Lebanese border. The United States is building a prototype Airborne Laser consisting of a powerful laser mounted on a Boeing 747, and its first test against a theatre ballistic missile is scheduled for 2003. The US Defense Department created the High Energy Laser Joint Technology Office in June 2000 to speed up the various armed

- services' efforts to develop laser weaponry.
13. Other technological advances in sensors, communications, and materials are already finding their way into new military systems. And - as previously investigated by this Committee - new technologies are being developed for so-called "non-lethal weapons", such as incapacitating sticky foams, acoustic devices, anti-traction substances, super-adhesives, and anti-personnel electric stun guns.
 14. Technologies still in the research area are expected to have far-reaching military and civilian applications. Quantum physics, for instance, could revolutionise information processing in ways that would have a major impact on weapons design, cryptography and communications. Nanotechnology - the production of microscopic machines - could present new ways of incapacitating military equipment.
 15. "Emerging technologies" is an extremely broad term into which everything could be thrown, but for the purposes of this report, we will not address information and computer technologies or bio-weapons and bio-engineering (which have already been analysed in other Committee or Sub-Committee reports). This report will consider non-lethal weapons, weapons in space and nanotechnologies, a diverse group of technologies that should provide a small sample of developments to come.

A. NON-LETHAL WEAPONS

16. The category "non-lethal weapons" (hereafter NLW) includes a wide spectrum of disparate weapons technologies which have a range of different effects. The US Department of Defense (DoD) defines non-lethal weapons as "discriminate weapons that are explicitly designed and employed to incapacitate personnel or material, while minimizing fatalities and undesired damage to property and the environment". Some of the most frequently-mentioned NLWs include acoustics (infra-sound and stun technologies); biological and medical agents (incapacitating and calming substances); chemicals (adhesives, corrosives and embrittling substances); and electromagnetic weapons (lasers and microwaves). It is important to note that most usages of the term NLW do not necessarily imply that the weapons do not incur fatalities.
17. In 1998, a Joint Non-Lethal Weapons Program was founded in the United States, following a Congressional initiative in 1996, with the intent to provide the US DoD with an integrated and co-ordinated non-lethal weapons programme. The US Marine Corps is the executive agent of the project which is co-ordinated by the Non-Lethal Weapons Directorate. The purpose of the programme is to "broaden the set of responses and options available to our senior political and military decision-makers ... [and] provide flexible and selective engagement capabilities that contribute to mission accomplishment and have utility in combat operations in major theatre war (MTW) [and] in execution of military operations other

than war [MOOTW]". In 2000, the US budget for federal research on non-lethal weapons was US\$24 million. In the research and development area, one of the pioneer institutions in the field is the Non-Lethal Technology Innovation Center, based at the University of New Hampshire and started with the help of Senator Robert Smith. The Center works closely with the Non-Lethal Weapons Directorate.

18. Non-lethal weapons are already being employed, or at least tested, in various operations. The US Marines, for instance, already use a type of foam to disable metal equipment. The same corps is currently developing the Vehicle-Mounted Active Denial System (VMADS), a microwave-like field of energy that creates a sensation like a light bulb on skin. It uses a transmitter to send out a millimetre-length wave of energy at a target. The weapon, when used briefly, causes no long-term effects. Michael Murphy of the US Air Force Base on which development has occurred noted, "There is more physical damage to skin from exposure to visible light, such as sitting on a sunny beach, than from the energy that this technology exploits". The weapons could be used to deter crowds or to incapacitate enemies during an operation. The weapon has been under development for over a decade and \$40 million have been invested in it so far; a prototype could be ready as early as the end of 2001.
19. The Pentagon is currently developing a stink bomb that would repel enemy troops or unruly crowds. The researchers developing the bomb note that there is a correlation between fear and nasty smells, because both activate tissue deep in the brain, the *New Scientist* magazine reported. Researchers have tried to deal with the fact that various odours cause different responses in different cultures, but one team of researchers isolated two smells that seemed to transcend cultural differences and combined them to produce the stink bomb.
20. The British Home Office and the Ministry of Defence Research and Development Agency (DERA) are also carrying out tests on NLWs. This summer British police will conduct trial tests on a glue gun that fires a pellet of compressed glue which expands to 30 times its original size and covers demonstrators, impeding their movements and making it difficult for them to carry on with their protest. This instrument may be used to quell disturbances in Northern Ireland.
21. The French armed forces are also developing and testing their own NLWs. In a 1999 article in the French defence magazine *Les cahiers de Mars*, General Jean-Pierre Kelche, French Chief of Staff, made a case for the use of NLWs in military operations. The French military is interested in NLWs, he wrote, primarily as defensive tools and as a substitute for the prohibited anti-personnel mines. In fact, according to the Defence Ministry's definition, NLWs should have "the specific purpose of temporarily incapacitating human physical action and psychological abilities to the point of neutralisation: their effects should be limited, reversible and possibly without consequences". The *Délégation*

générale pour l'Armement (DGA) is working on a 30-year prospective plan for the conduct of future military operations that includes the use of techniques and weapons to minimise casualties as much as possible. The DGA's weapons laboratories in Gramat are experimenting on about 50 different types of NLWs including glues, nets, electrical guns, blinding grenades, non-lethal incapacitating gases, microwave guns and soft, non-explosive, large-calibre bullets.

22. NATO is also in the process of developing a comprehensive policy on NLWs, following a 1999 directive on the issue. NATO defines NLWs as weapons which are explicitly designed and developed to incapacitate or repel personnel, with a low probability of fatality or permanent injury, or to disable equipment, with minimal undesired damage or impact on the environment. NATO views NLWs as a complement the use of weapons, which will enable NATO forces to achieve their objectives in military missions, limiting escalation, improving force protection, or repelling personnel. NATO, however, sees NLWs as in no way limiting a commander's ability to take action in self-defence, nor does it raise standards or impose further restrictions on the use of force. NATO planners are taking NLWs into account when planning for various missions and, from 2001 to 2005, applicable divisions will study the technologies, their human effects and their cost effectiveness.
23. The US-based Council on Foreign Relations convened an independent task force on NLWs in which they concluded that despite the presence of the NLWD, the DoD has been slow to take up the subject of NLWs. They also imagined a few things that might have been conducted differently during the 1999 NATO intervention, including jamming Serbian air waves so as to disable the Serbian media monopoly; the precise delivery of revolting smells could have forced military headquarters personnel to evacuate their buildings; the application of super-adhesives could have rendered bridges unusable (an alternative to bombing). In conclusion, the Council on Foreign Relations report suggested that there would be an overall benefit resulting from large-scale investment in non-lethal weapons.

1. Non-lethal?

24. While the development of non-lethal weapons is fuelled by a desire to minimise injuries and, in some cases, by a disdain for violence, some of these technologies, however, raise important humanitarian and arms control issues which are being studied by international organisations such as the International Committee of the Red Cross (ICRC) and the United Nations. An expert on NLWs, Professor David P. Fidler of Indiana University, cautioned, "If NLWs become more sophisticated and powerful, their potential may alter how experts look at the morality and legality of humanitarian intervention, anticipatory self-defence, enforcement of sanctions and attacks on terrorist groups ... the relationship between international law and NLWs will be more complex. controversial

and dangerous than people may realise."

25. Each class of NLW raises different legal questions depending on the relevant convention governing its use, including (but not limited to) the Biological Weapons Convention, the Chemical Weapons Convention, the Law of Armed Conflict (LOAC) and the Inhumane Weapons Convention. For example, biodegrading microbes that could eat away at certain types of material surfaces would raise issues under the 1972 Biological Weapons Convention. The parties to that convention pledged never to produce, stockpile or otherwise acquire "(1) Microbial or other biological agents, or toxins whatever their origin or method of production, of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes; (2) Weapons, equipment or means of delivery designed to use such agents or toxins for hostile purposes or in armed conflict". Similarly, the use of certain non-lethal weapons against enemy troops might be in breach of the 1993 Chemical Weapons Convention.
26. US military planners would like to see these treaties opened for review so that they will have the green light when it comes to developing new forms of NLWs. Colonel George Fenton, who heads the NLW Directorate, told the *New Scientist* magazine that he would like, "... a magic dust that would put everyone in a building to sleep, combatants and non-combatants". Such dust would obviously necessitate a review of existing international agreements.
27. During a visit to Geneva in June 2000, this Committee learned that the International Committee of the Red Cross (ICRC) is studying the effects of non-lethal weapons on health and how they would be used in light of international humanitarian laws. According to the conclusions presented by Dr Robin Coupland, all references to "lethal" and "non-lethal" weapons oversimplify and are thus misleading. NLWs such as sticky foams, infrasound and electromagnetic waves can indeed have some effects on health depending upon the circumstances in which they are deployed or on their possible combination with existing conventional weapons.
28. The ICRC also emphasized that the military use of NLWs against civilians could undermine existing norms of international law pertaining to armed conflict, as well as the 1993 Chemical Weapons Convention and the 1925 Geneva Protocol. ICRC recommended that current efforts to integrate NLWs into operations should address the legal, health-related and tactical implications of doing so.
29. In addition, at its 27th International Conference in November 1999, the ICRC made specific proposals to all states based on its SIrUS (Superfluous Injury or Unnecessary Suffering) project. The project attempted to bring objectivity to the notion of "superfluous injury and unnecessary suffering", based on the study of data relating to the effects of weapons used in conflict over the last 50 years. From these data, an expert group has established a list of effects of weapons that have not been seen commonly in the last five decades and that can be defined as undesirable. The ICRC has therefore

invited states, when reviewing the legality of a weapon, to take the SIRUS Project findings into account by

- establishing whether the weapon in question would cause any "superfluous injury and unnecessary suffering";
- weighing the military utility against these effects;
- determining whether the same purpose could be reasonably achieved by other lawful means that do not have such effects

30. The ICRC also encouraged states to make new efforts to build common understanding of the norms to be applied in review of these new weapons and to promote transparency in the conduct and result of such reviews. In January 2001, as a follow-up to the International Conference, the ICRC held an Expert Meeting, with representatives of over 20 countries attending, in order for experts on the topic to exchange notes on various state practices and legal reviews of weapons. The meeting surveyed the various existing national practices. In Sweden, for example, an independent decision-making committee was established in 1974 to review the legality of weapons utilized in that country. The US has undertaken reviews of weapons also since 1974 as part of its law of war programme. Representatives from Norway, Germany and Australia also presented information about their weapons review processes.
31. *Human Rights Watch* (HRW) has expressed concern about some types of non-lethal weapons under development. The organisation takes no position on non-lethal weapons per se, but it reviews specific weapons programmes for their consistency with domestic and international humanitarian law. They have been most actively following the development of acoustic and microwave weapons and blinding lasers. HRW believes that acoustic weapons should be subject to a complete legal and humanitarian review before states continue with current development programmes. While acoustic weapons are non-lethal and not designed to cause deafness per se, at the right frequencies they could cause permanent physical damage, not to mention interference with the central nervous system. HRW was one of the first organisations to open the subject for debate among governmental and non-governmental organisations alike; they questioned the military utility of these programmes given that they are indiscriminate and affect civilians and military personnel alike.
32. The debate on non-lethal weapons is also quietly raging in domestic police departments in the United States and Europe, where these technologies have either already been adopted or are ready for adoption by a wider range of the police force patrolling the streets. For example, when Boston Police Commissioner suggested the introduction of lead-filled socks which, when fired, can incapacitate a suspect without killing him, the local union resisted, saying the new weapons was untested. In many cases, the technology in question is not completely new; previously, however, it was limited to a select group of officers. The mass introduction of NLWs brings into question the use of force, not to mention certain employment contracts. Advocates argue that with

increasing numbers of mistaken police shootings -- the Amadou Diallo case in New York City in which four police officers shot and killed an unarmed man is perhaps the best known -- the use of NLWs will give officers in the field more options. In addition, in both domestic and international police or military actions when suspects or enemies are mixed with innocent civilians, they argue, NLWs may be useful.

B. WEAPONS IN SPACE

1. The US programme

33. When the United States conducted a test of its missile defence system in July 2001 as part of its National Missile Defence programme (NMD), some critics of the programme noted that the Bush administration's foray into missile defence was merely part of the administration's larger designs to develop programmes for Weapons in Space (WIS). Indeed, the Pentagon recently admitted that its NMD programme would include land, sea, air and space-based weapons. In January, the Air Force held its first major space war game, driven by a scenario that there would be tension with China in the year 2017. In the scenario, the opposing nations possessed micro-satellites which could jam transmissions and fry electronics with radiation - a form of warfare which combined non-lethal weapons, weapons in space and nanotechnologies.
34. Ronald Reagan first proposed the Strategic Defense Initiative (SDI) - the so-called "Star Wars" programme - back in the 1980s and today the Defense Department has revived almost every major element of that original programme. The change in focus to air and space has happened while US Defense Secretary Donald Rumsfeld has conducted over 20 military reviews. These reviews have been mostly internal to date, with little public information available. NATO Allies, not to mention the American public, currently await the results, along with the presentation of the administration's new and comprehensive defence strategy. Symbolically, the shift in national defense priorities is demonstrated in some of the changes that have already been made: Defense Secretary Rumsfeld has appointed a four star general to lead an integrated, better-funded military space programme. In addition, the long-held requirement that the US be prepared to fight two regional wars simultaneously will be dropped. A change in this long-held axiom of US military preparedness would indeed mark a tremendous sea-change in military strategy.
35. Proponents of the shift in military thinking argue that if space is not militarised and used by the United States, someone else will get to it first. US Senator Robert Smith - the chief "space hawk" in Congress, as *The Economist* referred to him - recently commented, "To those who say we can't militarise space, I must say, **CD**Do you want somebody else to do it". In addition, they argue that because post-industrial economies depend on satellite communications that sustain banking and financial svstems. not to mention phones. an

attack on these systems could have the potential to devastate the day-to-day functions of a country. Thus, space has taken on a new strategic priority.

36. The theoretical basis for this change to an emphasis in space started during the Clinton administration. In 1997, the US Space Command published its report "Vision for 2020" as part of the future exercises of the US armed forces. Arguing that the increasing use of space could lead to new vulnerabilities, the report stated that space had become "the fourth medium of warfare - along with land, sea and air". In its Long Range Plan, published in 1998, the US Space Command foresaw a role for itself in "dominating the space dimension of military operations to protect US national interest and investment ... [and] integrating space forces into warfighting capabilities across the full spectrum of conflict".
37. The Commission to Access United States National Security Space Management and Organization (or the Space Commission) headed by Donald Rumsfeld and established in 2000 with the support of members of Congress (including Senator Smith), issued a final report on 11 January of this year. The Rumsfeld Report underlines the strategic importance of an "offensive" approach with respect to space: "Having shown the world the utility of space systems, it would be pretty naïve to think that our adversaries are going to sit around idly and not developing their own space-based information capabilities and the tools and techniques to counter the current US space advantage". The United States, argues the report, must ensure continuing superiority in space capabilities and that "The President will have the option to deploy weapons in space to deter threats to and, if necessary, defend against attacks on US interests".
38. The US armed forces, argued the Rumsfeld Report, would need to transform their capabilities in the areas of
 - assured access to space and in-orbit operations;
 - space situational awareness;
 - earth surveillance from space;
 - global command, control and communications in space;
 - defence in space;
 - power projection in, from and through space.
39. Immediately after the Rumsfeld Report was published, the DoD started to implement some of its recommendations. On 2 May, the Defense Secretary declared, "There is no question that the use of land and sea and air and space are all things that need to be considered if one is looking at the best way to provide the kind of security from ballistic missiles that is desirable for the United States and for our friends and Allies". The US Air Force will be responsible for WIS programmes, to overcome inter-service rivalry. Not surprisingly, in July 2001 General Michael Ryan, the air force chief of staff, endorsed the deployment of space-based weapons to protect US assets in space. He also predicted that by 2020 the United States will be able to shoot down other countries' orbiting spacecraft.
40. The weapons that the US DoD plans to deploy in space should be

of two types: directed-energy weapons (i.e. powerful lasers) and kinetic-energy weapons (missiles that hit and destroy space objects without carrying explosives). The most powerful US laser is the Mid-Infrared Advanced Chemical Laser (MIRACL) run by the Army at White Sands, New Mexico. Although capable of destroying a satellite from the ground, it is however too heavy to be put in orbit. A less powerful space-based laser (SBL) is being developed jointly by TRW, Lockheed Martin and Boeing. Financed by the US Air Force and the Ballistic Missile Defense Organization (BMDO), the system will probably be tested in 2012. Kinetic-energy anti-satellite weapons (ASATS) were successfully tested by the Air Force in the 1980s. More recently, the Bush administration has revived an army programme, the KE-ASAT, which the Clinton administration had cancelled. For the moment, space-to-earth weapons are quite remote and more controversial.

41. The Bush administration's plans to put weapons in space have been severely criticised by the US Senate majority leader, Tom Daschle, who defined them as "the single dumbest thing I have heard so far from this administration". He also added that "It would be a disaster for us to put weapons in space of any kind under any circumstances. It only invites other countries to do the same thing". Other Democrats in Congress are planning to propose legislation to ban weapons in space. But there are critics also within the armed forces: Lt Col Bruce M. DeBlois of the US Air Force published a detailed study in 1997 on the weaponisation of space. While recognising that being the first nation to put weapons in space would have undeniable advantages, DeBlois argued that such move would be profoundly destabilising and would encourage a high-tech arms race in which the United States had the most to lose. He concluded by advocating the pursuit of a "space sanctuary" through multilateral agreements and passive, ground-based defences.

2. International Reactions

42. The changes in US defence priorities have not gone unnoticed in the world. Notably, Canada's Foreign Ministry has declared that it strongly opposes the weaponisation of space at all costs. The Foreign Affairs Minister, John Manley, commented that unilateral action by the United States "will lead to confrontation. And that is a cause of greater insecurity for the United States and for the rest of the world." The Canadians have said they would take the lead in drafting an international convention that would ban weapons in space.
43. French President Jacques Chirac, in response to US plans, declared on 8 June, during his traditional annual speech at the *Institut des Hautes Etudes de Défense Nationale* that "non-militarisation of space" was an "essential element" of international security and "must be maintained". He added that he rejected any ballistic-missile defence system that would lead to the deployment of interceptors in space.
44. On 16 July 2001, a joint statement by Russian President Vladimir

Putin and Chinese President Jiang Zemin proclaimed "an urgent need to prevent weapons being placed in space and for international accords to be concluded on introducing a ban on putting weapons in space". To this end, the document noted, "Russia and China are in favour of creating a special committee to prevent an arms race in space." In addition, at the most recent meeting of the Conference on Disarmament (CD), the Chinese Ambassador submitted a working paper entitled "Possible Elements of the Future International Legal Instrument on the Prevention of the Weaponisation of Outer Space". The ambassador argued that the weaponisation of space was in no country's interest and that an international legal agreement preventing weapons in space was necessary. He urged the Conference on Disarmament, as the only multilateral negotiating forum on disarmament, to take up the issue.

45. It is important to note that US relations with both Russia and China are particularly delicate at this stage because of Washington's missile defence plans. During President George W. Bush's recent meeting with Vladimir Putin at the G8 summit in Genoa, the two leaders agreed to tie NMD to a reduction of their offensive strategic missiles. Russia's position on NMD has been ambiguous at best. After initial opposition to NMD, a senior Russian general has hinted that missile defence may be slightly more accepted in recent months, and the Russians announced that they would not rule out the modification of the 1972 Anti-Ballistic Missile Treaty. President Putin is opposed to scrapping the ABM Treaty completely, but Bush has offered a new treaty at a kind of compromise. A joint statement issued at Genoa by Bush and Putin said that "[the leaders] agreed that major changes in the world required concrete discussions of both offensive and defensive systems." Analysts note that it is not clear, however, what exactly was agreed in Genoa, but the parties will have "intensive consultations" about the issue after the summit. When pressured by the Russian press after his return from Italy, Putin reaffirmed his position that Russia opposes any alterations to the ABM Treaty, stating that there was no principle breakthrough during the G8 Summit.
46. Given the instability in US-Russia relations, any further plans to develop a fully-fledged Weapons in Space programme may unravel this delicate relationship. The same is true of the relations between the United States and China. Moreover, despite its notorious financial problems, Russia has been pursuing developments in space, and Beijing probably has a limited military space programme.
47. On 16 January 2001, President Putin signed a package which is said to have contained more than 30 directives to reform Russia's military structures. Under this plan, the Missile Space Defence Forces and the Military Space Forces will be separated from the Strategic Missile Forces structure and they will become autonomous sub-units in 2002. Thus, President Putin emphasized the importance of developing Russian Space Forces as an

independent program. After his appointment as Minister of Defence in March 2001, Sergei Ivanov immediately announced a new plan of military reform, also declaring that one of his priorities was creating a new branch of the armed forces, the Military Space Forces, separate from the Strategic Missile Forces. He made statements suggesting that the Space Forces could provide tactical support to other military divisions. Given the perilous state of Russia's military satellite system and the overall deterioration of Russian military forces, the above-mentioned chain of statements seems nothing more than a properly-planned Kremlin PR campaign.

48. According to a 1998 US Congressional report, China is acquiring a number of foreign technologies which could be used to develop an anti-satellite (ASAT) capability. Beijing may also be developing an advanced radar system capable of tracking satellites in low earth orbit and jammers which could be used against Global Positioning System (GPS) receivers. China is also reportedly very interested in laser technology. The country's manned space programme, the US report stated, "could contribute to improved military space systems in the 2010-2020 time frame". However, in its 2000 White Paper on defence policies, China declares itself "strongly opposed to an arms race in outer space", adding that "the testing, deployment or use of weapons, weapons systems or their components should be banned in outer space".

3. International Legal Aspects

49. Any programme to develop weapons in space is governed by the relevant international treaties that deal with space, weapons development and arms control. This includes the Outer Space Treaty of 1967 (OST), which lays out the principles governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies. The first principle governing the treaty states that "the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of mankind."
50. US defence planners have been dealing with interpretations of the legal language utilised in this treaty in order to find loopholes for future weapons development. For example, the treaty states that "no nuclear weapons or other weapons of mass destruction may be placed in the earth orbit, installed on celestial bodies or otherwise stationed in outer space". Some international legal observers argue that if an international convention does not specifically outlaw something then it is permissible. Thus, while the OST treaty specifically declares that nuclear weapons or WMD are not allowed in space, a wide array of other weapons are permitted under international law, thus paving the way for various types of weapons development.
51. A plan to develop WIS will broach many international legal questions that have not yet been dealt with. Even basic terminology has no definition: for example, what constitutes outer space itself is

not defined. The Soviet Union suggested an altitude of 100 km as the inner/outer space boundary, but the relevant UN Committee on Peaceful Uses of Outer Space has never formalized this proposal. A legal definition of outer space has its drawbacks for those states that do not want to see their actions limited by the presence of a (legal) boundary. Again, legal uncertainties provide opportunities for weapons developers: Major Elizabeth Kelly, Chief of Space and International Law for the US Air Force Space Command, noted the OST prohibits testing on celestial bodies, but "it's silent on testing weapons in outer space itself".

52. Plans to develop weapons in space are imminent and it is thus imperative that there be general discussion about the planned range of technologies to be employed, not to mention possible forums for arms controls. Rebecca Johnson of the Acronym Institute noted that three elements would need to be present in any treaty to prohibit weapons and war in space: 1) a ban on the development and use of weapons in space which would strengthen and expand the 1967 treaty; 2) a ban on the testing and deployment of anti-satellite weapons; 3) the establishment of a code for peaceful and non-aggressive uses of space. The issue, however, is being followed by members of the international community, and the UN General Assembly adopted a resolution on the prevention of an arms race in outer space on 3 January 2001, urging member states to look for further multilateral and bilateral measures which will help prevent an arms race in outer space.

C. NANOTECHNOLOGIES

53. Nanotechnology, sometimes referred to as molecular nanotechnology, is the science of building things at an unthinkable small scale, a size range from 1 to 100 billionths of a metre, with what might be called nanoscopic precision, molecule by molecule. The term nanotechnology itself comprises a diverse group of technologies and innovations that include nanorobotics, nanomedicine, nanomaterials, nanoengineering etc., and involve researchers in chemistry, physics, materials science and molecular biology. The purpose is to build almost any structure consistent with the laws of physics and chemistry that can be specified in atomic detail - in other words, everything from space ships to human organs. Building a nanotechnology requires working from the bottom up, constructing objects from their most basic materials. This would offer an unprecedented degree of precision and control over the final product.
54. The potential impact of nanotechnology is enormous. It will permit the creation of better products requiring less material and less energy and polluting less. All kinds of land, sea and space vehicles, for example, could be made lighter, stronger and more fuel-efficient. Nanotechnology would also allow the creation of incredibly small computers to be imbedded in almost every material: paint, clothing, medical instruments. According to a 1997 US DoD report. for instance. nanorobotics and nanomedicine could

become a reality by 2020. Possible applications include programmable immune machines that travel through the bloodstream of a patient to perform surgery, just as the one imagined by Isaac Asimov in the 1965 science fiction classic "Fantastic Voyage".

55. The field was started back in 1985 after Richard Smalley, a Nobel prize-winning chemist, discovered a form of carbon that could be used as a raw material for these miniature devices. More recently, scientists have gained the ability to observe and manipulate atoms directly. Researchers at Rice and Yale Universities have taken the first steps toward the creation of molecular circuits which would replace the current silicon chips. Early forms of nanomedicine involving engineered molecules (though not yet devices built at the molecular scale) are already being tested on patients.
56. However, the ability to make commercial products may yet be a few decades away. Theoretical and computational models indicate that molecular manufacturing systems are possible - that they do not violate existing physical laws. These models also give us a feel for what a molecular manufacturing system might look like. Today, scientists are devising numerous tools and techniques that will be needed to transform nanotechnology from computer models into reality. While most remain in the realm of theory, there appears to be no fundamental barrier to their development.
57. States have made serious investment in the field of nanotechnology. In 2000, the Clinton Administration started National Nanotechnology Initiative (NNI), a measure which included a \$497 million investment in the field. Several agencies, such as the National Science Foundation, DoD, the Department of Energy and NASA, will participate in the programme. Six university research centres are scheduled to open in the United States, as 70% of the new funding will go to university based research. The European Union runs several different nanotechnology research centres, including NanoNetwork, which has 18 member research centers. Japan, Singapore, China, Australia, Canada, Germany, the United Kingdom and Russia all support nanotechnology efforts.
58. Governments and researchers see nanotechnologies as having overwhelmingly benevolent means, but not everyone agrees. In 1986, K. Eric Drexler, a science theoretician, wrote a now-classic book on nanotechnology, "Engines of Creation", explaining the basics of the science and its potential applications. He described how manipulation of matter at the atomic level could create a utopian future of abundance, where just about everything could be made cheaply, and almost any imaginable physical problem could be solved using nanotechnology and artificial intelligences. But Drexler applied his imagination also to the potential downside. The ability to create self-replicating nanotechnologies, he warned, certainly has potential for grave misuse. In a world where molecular-level "assemblers" will run atomic-scale assembly lines to fabricate everything we need, new "plants", or "bacteria", for instance, could replicate themselves ad infinitum. thus consuming

- everything in their path, including plants, animals and humans.
59. For many years, Drexler's dystopias were dismissed as utterly implausible. But in April 2000, Bill Joy, co-founder and chief scientist of Sun Microsystems, the leading IT firm in Silicon Valley, argued in a long article in *Wired* magazine that Drexler's prophecies of doom were indeed possible. He had learned that self-reproducing nanomachines, although perhaps not around the corner, were becoming all too plausible. Joy considered the threat of possible misuses of nanotechnologies in the 21st-century considerably more worrying than the threat of weapons of mass destruction proliferation. "Nanotechnology has clear military and terrorist uses", he explained, "and you need not be suicidal to release a massively destructive nanotechnological device - such devices can be built to be selectively destructive, affecting, for example, only a certain geographical area or a group of people who are genetically distinct". Therefore, he concluded that research into nanotechnology and other fields, such as genetics and robotics, should be stopped before it becomes too dangerous for humanity.
60. Others expressed similar concerns. The Foresight Institute, a non-profit organisation of nanotechnology supporters, issued some detailed guidelines encouraging governmental supervision of nanotechnology development. Such supervision could help prevent accidental catastrophes, much as government agencies are helping the emerging biotechnology industry avoid accidental releases of undesirable genetically-modified organisms. According to this view, regulatory control will be necessary to ensure that nanotechnology is developed carefully: safe designs, safe experimental procedures and methods to test for potentially hazardous molecular-level "assemblers" can be incorporated into standards by consensus of all interested parties (i.e. government, research institutes, private companies).
-

IV. CONCLUSIONS

61. In his article in *Wired* magazine, Bill Joy also reflected on the nature of progress in the sciences this century. As one of the individuals who has been at the forefront of scientific inquiry, he issued a warning that shocked some of his colleagues in the scientific community.

"The 21st century technologies - genetics, nanotechnology, and robotics - are so powerful that they spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw materials. Knowledge alone will enable the use of them. Thus we have the possibility not just

of weapons of mass destruction but of knowledge-enabled mass destruction (KMD), this destructiveness hugely amplified by the power of self-replication."

62. He continued, "I think it is no exaggeration to say we are on the cusp of the further perfection of extreme evil, an evil whose possibility spreads well beyond that which weapons of mass destruction bequeathed to the nation-states, on to a surprising and terrible empowerment of extreme individuals."
63. Joy encouraged his colleagues to discuss the nature of scientific development in open forums and to reflect on the nature, pace and consequences of scientific developments like nanotechnologies. After recalling the famous physicist Freeman Dyson's comment that the atomic bomb was dropped because no one had the courage or the foresight to say no, he added, "The experiences of atomic scientists clearly show that things will move too fast, and the way in which a process can take on a life of its own." The need for control of these new technologies is more important now than in previous times of scientific development.
64. Technology has always challenged arms control. The desire to maintain the upper hand in battle has often driven the development of more sophisticated weaponry although, increasingly, advances in military technology have had their origin in the civil sector. Regardless of origin, however, the notion that new technology should be regulated to preserve stability and rule out particularly unpleasant forms of warfare is not a recent idea.
65. Probably the best-known example of this is the development of the atom bomb and subsequent efforts to develop bilateral agreements between the two dominant nuclear powers - the United States and the former Soviet Union - and to develop multilateral arrangements to restrict the spread of nuclear weapons technology to other nations. The fruits of these efforts are well known: the ABM Treaty, SALT, START, the INF Treaty and the NPT, to name just a few.
66. Although these agreements all concern nuclear weapons (or defences against them), the Non-Proliferation Treaty differs from the others in several significant ways. Unlike the others, it is multilateral rather than bilateral, it concerns a technology with both military and peaceful applications, and it embodies a "bargain" whereby nuclear weapons nations agree to assist non-nuclear weapons nations to exploit civilian nuclear technology, provided that they agree to forego nuclear weapons. This latter feature - rewards in return for restraint - is also a central element in the Chemical Weapons Convention.
67. Such regimes, however, are not the only arms control models that can be applied to technologies. During the Cold War, exports of dual-use technology were regulated by the Co-ordinating Committee on Multilateral Export Controls (COCOM), and although this body no longer exists, there still are multilateral "suppliers regimes" for nuclear, chemical and missile technologies. These types of multilateral frameworks, which deal with

technologies with both military and civilian applications, are clearly the most promising models for future regimes relating to emerging technologies, especially given the prevalence of convergence of the technologies employed.

68. The central question is, therefore, not whether but how arms control can be implemented with regard to emerging technologies. Three potential areas have been identified in this report: non-lethal weapons, weapons in space and nanotechnologies. A more rigorous analysis would certainly have to address other types of emerging technologies, but these serve as useful examples.
69. In 1996, the German Bundestag produced a comprehensive report on "Control criteria for assessment and decision-making on new technologies in the defence sector" which emphasised the need for early observation and analysis of militarily relevant technologies, assessment of potential problematic consequences and political planning at national and international levels, the three integral components of preventive arms control. The report sees preventive arms control as "a variation of qualitative arms control" which "attempts to prevent or limit problematic developments early on that could result from arms technology innovations". The Bundestag document suggested that criteria for preventive arms control should be included as early as possible in the assessment and planning of militarily relevant research, development and testing activities. "By exerting influence on lines of technological development", the report added, "potential future military options considered undesirable are to be limited and new technological arms races slowed".
70. The technologies analysed in this report may open international legal agreements to questions or open the way to new international legislation. The United Nations General Assembly has tried to establish some general principles for the international promotion of science and technology for peaceful purposes in several resolutions. The most recent one, approved in October 2000, affirmed that "scientific and technological progress should be used for the benefit of all mankind to promote the sustainable economic and social development of all States and to safeguard international security". The General Assembly document added that "international co-operation in the use of science and technology through the transfer and exchange of technological know-how for peaceful purposes should be promoted".
71. Your Rapporteur is convinced, as a general principle, that the full range of possible effects of all new technologies with likely military applications should be studied in depth before defence ministries are given the green light for their introduction. More specifically, with regard to the technologies examined in this report, a few indications emerge from the above analysis. Non-lethal weapons may clearly have some useful application in both police and military operations. Moreover, this is an area in which Europeans could compensate some of their technological imbalances with the United States. It is essential, however, that the international community, and NATO countries in particular, should

- continue to study the effects of non-lethal weapons on health and how they would be used in light of international humanitarian laws and multilateral arms control agreements;
 - address the legal, health and tactical implications of current efforts to integrate NLWs into operations;
 - recognise the notion of "superfluous injury and unnecessary suffering" and carry out legal reviews when studying, developing, acquiring or adopting any new weapons.
72. With regard to weapons in space, your Rapporteur believes that all attempts to dominate space militarily could have destabilising consequences for global security. They could risk an arms race and increase the vulnerability of important commercial, communication, verification and intelligence assets in space. Thus, it is urgent to
- discuss and develop, in the context of the relevant international fora, a new international treaty to ban the development and use of weapons in space which would strengthen and expand the 1967 treaty;
 - include in this treaty a ban on the testing and deployment of anti-satellite weapons;
 - establish, as a corollary to the above treaty, a code for peaceful and non-aggressive uses of space.
73. It is more difficult, at this stage, to offer clear policy recommendations for nanotechnologies. The ability to manipulate atoms and create (or re-create) almost any material or structure has certainly the potential to revolutionise not simply military operations, but the entire human civilisation. It is easy to understand, for instance, how nanotechnology could lead to revolutionary applications in the fields of medicine, engineering, information technology and so on. What is probably still in the realm of science fiction is the sort of utopian (or dystopian) world depicted by Drexler and other theoreticians. However, even if that is only a hint of how the future will look, we have to agree that the extreme caution suggested by Bill Joy is not out of place. Therefore, as of now, it is advisable that governments and relevant international organisations pay attention to the developments of nanotechnology and be involved, together with scientists, in the development process.