

CIVIL-MILITARY AMBIVALENCE OF SCIENCE AND THE PROBLEM OF QUALITATIVE ARMS CONTROL -  
AN EXAMPLE OF LASER ISOTOPE SEPARATION

Wolfgang Liebert and Götz Neuneck

**4.1 The connection of science and armament dynamics or the problem of qualitative arms control**

The East-West conflict has been declared over, but armament dynamics seems unbroken. The forty years of confrontation in the Cold War provided the justification for a dangerous quantitative and qualitative arms race. The deployment of intercontinental ballistic missiles, nuclear armed submarines, bombers, sundry nuclear warheads, conventional precision weapons and much more, was legitimized by the threat by the opposing side. The loss of these dubious grounds makes military strategists and planners look for new scenarios of threat and suggest -as before- the strategy of military strength and the development of up to date weaponry. These weapons are the result of many years of intensive research and development.

Despite the continuation of the concept of nuclear deterrence, there are doubtlessly steps toward disarmament. But it seems to us that there is a risk of a qualitative arms build-up going ahead in the shade of a step-wise quantitative disarmament. It is evident that at least one source of the competition of armaments is not being blocked: the scientific research and development (R&D) which stimulates the armament dynamics.

At the beginning of the development of a new weapon there is often a scientific idea or a technological breakthrough which can be relevant for military purposes after some additional years of intense R&D. At the end a new weapon has been born after an enduring process of interactions between industry and government, basic and applied science, university and bureaucracy, strategy and politics. Of course, a scientific breakthrough *per se* does not directly influence arms policy; it must be translated into weapon systems and strategies as well.

When submitting the budget bill for the fiscal years 1992 and 1993 the US Secretary of Defense Richard Cheney stated in February 1991:2

This will be a decade of development more than of production.

This statement seems to be old Cold War thinking: it claims that it is still necessary to explore all technological possibilities and to test in advance. It is based upon the worst case assumption that the opposite side is presumably doing the same. This position cannot be maintained today. If the arms race is really supposed to be halted, then, at least after the declared end of the Cold War, arms control efforts should begin before testing, production or deployment of new weaponry. Hence, arms control should begin at the early stage of research and development (R&D).3

It is worthwhile having a look at some figures concerning military R&D. In 1990, the three most powerful NATO countries (USA, UK and Germany) and France spent US\$ 50 billion on Military R&D. According to the Organisation for Economic Cooperation and Development (OECD, 1990), even now, the percentage of military R&D expenditures as part of the governmental R&D budget is in the US more than 60%, in the UK nearly 50%, and in France 37%. For the former Soviet Union unofficial estimates of about 50-80% are found in literature. The governmental requisition of R&D for dedicated military purposes is even now frighteningly high.

At the same time, the historical chance of a process of real disarmament appears at the horizon. But in the aftermath of the Gulf War, which appears a success for the allies by using highly sophisticated weapons, but a disaster for Kuwait and Iraq, the enduring development of military technology seems to be unavoidable in the future: a new strategy based on modern technology is announced by Richard Cheney:4

This new strategy also emphasizes that technological breakthroughs will change military art, even as our stealth fighters today carry a disproportionate role in the air war.

Nevertheless, if the beginning process of disarmament should be made irreversible, then we need to halt the process of qualitative rearmament.

**4.1.1 R&D and arms control**

The trends in the relation between science and the military can roughly be characterized as an increasing 'scientification of war' and as a consequence a 'militarization of science' in many countries.5 Sir Solly Zuckerman wrote already in 1966 (Zuckerman, 1966: VII, 3):

The decisions we make today in fields of science and technology determine the tactics, then the strategy, and finally the politics of tomorrow. (...) the claim that science is the major transforming force of our times is now heard more insistently in the military world than anywhere else.

This hypothesis of the 'technological imperative'<sup>6</sup> is not shared by all and there is no need to believe that the complex system of armament dynamics is essentially governed by the scientific-technological inputs alone. Yet, there should be general agreement that there is a significant influence of science within what can be called the 'political-academic-bureaucratic-military-industrial complex'. Of course, this complex has to be analyzed carefully from all sides,<sup>7</sup> but here we emphasize the scientific-technological input. This is even more important if ODE is dealing with qualitative advancements in the arms build-up.

Traditional arms control has not paid much attention to this issue. In its origin, arms control was defined more as a function of policies "to regulate some aspects of their military capability or potential. The arrangement may apply to the IDeation, amount, {eadiness, or types of military forces, weapons or facilities."<sup>8</sup> Hence, the traditional arms control approach basically aims at managing the arms build-up while maintaining deterrence, as J .Holst observed: "Basically the concept of arms control was a twin sister of the concept of nuclear deterrence." (Holst, 1991: 85) In the past, the guiding principles were parity and the establishment of upper limits rather than the aim of (complete) disarmament. Therefore it does not come as a surprise that high upper limits (e.g., SALT) and the neglect of foreseeable technological innovations (e.g., MIRV) have heated up the arms competition or that same arms control agreements have born in themselves the germ für their circumvention respectively.

Nevertheless, as discussed in chapter 10 of this volume, a lot of bi- and multilateral arms control treaties<sup>9</sup> (not all in force) contain same commitments which ODE could call first hesitating steps toward qualitative arms control by regional restrictions on testing, use, manufacturing, production or acquisition of mainly means of mass destruction.<sup>10</sup>

Also global restrictions on the development and testing of specific<sup>9</sup> weapon systems and components are explicitly mentioned in same agreements. <sup>11</sup>

For instance, the Biological Weapons Convention (BWC), signed in 1972, bans the development of biologically active substances and toxins usable as weapons, but the obvious fallacy to allow defensive biological R&D programmes constitutes a menace regarding the aims of that treaty. R&D and production für 'defensive preparations' can also be useful für all kinds of military preparations.<sup>12</sup>

To mention another example, in the Anti Ballistic Missile (ABM) Treaty, research and 'preliminary development' are not explicitly prohibited. Hence, the ABM treaty has not prevented billions of dollars to flow into the same programme whose destabilizing effects were discussed widely.

To establish measures für qualitative arms control ODE needs a broader knowledge of the scientific base für the armament invention process and an improved understanding of the underlying R&D process. How to include scientific research, an area hitherto underestimated in arms control and technology assessment, is the focus of this chapter. Within that focus, the main aspect discussed concerns the implications of the fact that it is, in practice, difficult to draw a line between civilian and military R&D. One main obstacle für exploring this task is that talking about the military use of basic research is taboo. On the other hand, the ongoing interest of the governments of highly developed countries in sophisticated and superior weapon systems has an inherent negative influence on qualitative arms control efforts including R&D.

## 4.2 The military use of civilian science

One argument against constraining (potentially) military destabilizing R&D in order to prevent new military technology, is the assumption that militarily relevant R&D and testing of modern weaponry could have a positive impact on civilian science and technology. This is the famous or notorious spin-off hypothesis. Indeed, there are historical examples (e.g., radar). But in 1990, the German Ministry of Science and Technology stated -based on expert opinion- that in the United States spin-off effects, understood as the use of military R&D für the civilian sector, is estimated to be only 5-6% and that in the German enterprises with strong interrelation of civilian and military programmes (e.g., in space industry) the spin-off effects are 10-15% at best.<sup>13</sup> Thus, the ministry has confirmed what other studies on spin-off<sup>14</sup> have claimed: blessed or fruitful spin-offs from military R&D which serve the civilian sector are much more a myth than reality today.

The opposite of the spin-off hypothesis is considerably more important: we are faced with the continuous military use of science even of make-believe civilian basic research. Obviously, this is well known by military planners. Two years ago Timothy Garden, a member of the British military establishment, wrote in regard to the example of high energy physics (Garden, 1989: 53):

Many military applications will undoubtedly be found, but many will emerge from civilian research rather than dedicated military research.

Recently, the Office of Technology Assessment of the US Congress found out that high technology is more and more developed within the civilian sector and after that it finds its way to an armament related use. (Congress, 1989: 6)

4.1 Total federal R&D expenditures of Germany in millions of Deutsche Mark (DM), the federal R&D fundings in the business and enterprise sector (BES), and the respective parts of the BMVg (Bundesministerium für Verteidigung, which is the German MoD) also given in percentages. 15

		1982	1990
federal R&D	total	11 552	15,022
	BMVg	2076	3,778
	in percentage	18,0%	25,2%
Federal R&O in BES	total	5492	5619
	BMVg	1337	2756
	in percentages	24,3%	49,0%

This is even more the case in Germany. Table 4.1 lists the total federal R&D expenditures and the federal R&D funds for the business and enterprise sector (BES), as well as the respective portions, financed by the Bundesministerium für Verteidigung (the German MOD). The latter surely is weapon related. The increase of military R&D expenditures up to a quarter of total federal R&D funding is shown, which is mainly due to an immense increase in direct funding of military industry R&D. One explanation for this tendency is given in a declaration of the German government before the German parliament:16

The Minister of Defence bases as a matter of principle his science and technology programmes on civilian science and technology. Only if unavoidable the civilian scientific-technological basis is filled up by its own programmes.

Moreover, the German Minister of Science and Technology (BMFT/BMWI) has announced that he tries to include military requirements in civilian R&D programmes in the sector of computer sciences. Also, he will supplement so-called add-on programmes to dual-use programmes in order to make military use of civilian programmes (BMFT/BMWI, 1989: 122).

Thus, the praxis in the German scientific community -which is traditionally much less militarized than that of the US- turns out to be a praxis of latent and (at least from the governmental side) conscious use of the so-called civilian sector of science and technology for military purposes.

This sort of trends makes it necessary to deal with the scientific base when devising arms control measures concerning R&D. The latent use of science for military purposes must be detected specifically. In doing this, one is faced with the problem of civil-military ambivalence of science.17

An important aim of the analysis would be the identification and understanding of the military related contents of civilian R&D programmes or programmes which stand in an international mix of military and civilian research. In order to obtain a basis for the decisionmaking on science and technology, one needs to analyze the civil-military ambivalence of science. We now turn to a discussion of this problem by means of an example.

### 4.3 The example of Laser Isotope Separation (us)

Just after the invention of the first lasers in the early 1960s of this century, their use as an intense monochromatic light source was discussed for isotope separation. Since the 1970s various pretentious R&D programmes have been under way in many countries. Some of them are standing in a rather civilian context; others are promoted by military authorities. For instance, the Lawrence Livermore National Laboratory runs two well funded programmes for the development of laser based isotope separation techniques: at least since 1973, the LIS programme has mainly been dealing with uranium enrichment, which is useful for producing reactor fuel and weapon related fissile material, whereas the Special Isotope Separation (SIS) programme, founded several years later, focuses on the separation of plutonium isotopes as part of the weapon programmes of the Department of Energy.

Isotopes of chemical elements have slightly different physical properties. This is due to the different numbers of neutrons in the atomic nuclei. There exist until now a lot of technologies for isotope separation, e.g., for separating the uranium isotope U-235 from U-238. Table 4.2 lists five of the most important enrichment technologies. The lasers are used for an isotopically selective change of physical properties of the atoms (changing the magnitude and/or direction of velocity, changing inneratomic energy levels, changing the charge of the atoms), in order to manage the separation of the different isotopes of a sort of atoms.

Table 4.2 Enrichment technologies in comparison 19

	separation factor	specific electrical power (W/k SWU)	needed power for production of 15 kg HEU Per year
calutron	~2 <sup>20</sup>	400	0.5MW
gaseous diffusion	1.004	200	
gas centrifuge	1.5	20	20kw
jet nozzle	1.015	250	
laser isotope separation	> 10	0.5+7.0 <sup>21</sup>	~ 5kW

Three different methods for laser isotope separation 22 are discussed:

### 1. Beam deflection

LIS by beam deflection is based on the isotopically selective absorption of directional irradiation of laser light within an atomic beam. This leads to the spontaneous emission of photons in all directions and therefore to a directional momentum transfer on atoms resulting in an isotopically selective velocity change of atoms and the deflection of the related atom beam (Ashkin, 1970).

The so-called laser cooling of atom or molecule beams (this cooling process is possible down to temperatures very close to the absolute point of zero) uses the same principle: beams of atoms or molecules can be stopped by scattering forces arising from thousands of photons from a counterpropagating laser.<sup>23</sup>

### 2. Atomic Vapour Laser Isotope Separation (AVUS)<sup>24</sup>

Within the AVUS process also a hot atomic vapour is irradiated by laser light. A tiny difference in electronic energy states of the different isotopes is used to excite only one of them. For example the energy gap between the corresponding levels of the two uranium isotopes U-235 and U-238 is about 50,000 times smaller than the energy of the used laser photons. Therefore, in order to excite only one of the isotopes without affecting the other, the laser frequencies must be tuneable to an very high accuracy of 1 part of 100,000. Subsequently, other laser frequencies can be used to raise the electron energy state of the excited atoms over the ionization threshold, so that the ionized isotopes can be separated by electro-magnetic fields from the others.

### 3. Molecular Laser Isotope Separation (MLIS)<sup>25</sup>

In molecular laser assisted isotope separation process the induced energy transitions involve changes in vibrational energy states of the molecules instead of electronic energies. For instance, cryogenically cooled uranium hexafluoride gas is irradiated by lasers such that only gas molecules containing U-235 can absorb energy while the other molecules remain unaffected. Further energy absorption by a second irradiation with ultra violet laser light or by infrared multiphoton absorption leads to a dissociation of uranium hexafluoride into uranium pentafluoride by loss of one of the fluoride atoms. Uranium pentafluoride containing U-235 can be filtered from the remaining uranium hexafluoride.

The scientific principles underlying all these methods are well known. The problems for technological use lie in the practical details and need intense R&D efforts. First of all, exact knowledge about all excitation levels of atoms or molecules which should be isotopically separated are needed, in order to find usable transitions for the separation procedure. In the case of uranium, one has to examine thousands of such energy levels, and even many more for molecular uranium hexafluoride. Very tuneable and powerful laser systems have to be developed, which must be appropriate to the energy term scheme of the regarded isotopes.

For the AVLIS process dye-lasers of visible light wavelength with different active media are of interest whereas for the MLIS process one is searching for appropriate infrared lasers, e.g., CO<sub>2</sub> lasers, or ultra-violet lasers such as free electron lasers.

Other problems for atomic methods are caused by the fact that very hot metal vapour is the feed material. Hot uranium or plutonium is highly reactive and corrosive, not more than one-half of the atoms exist in the ground energy level; high kinetic energy of U-238 atoms for example leads to a direct flow of these atoms to the product plates hence collecting not U-235 alone, charge exchange problems and self ionizing levels of excitation arise so that the isotopically selective process is diminished, etc. Throughput problems are based on shielding effects of the produced positive

ions which reduce the extraction effect by electrical fields. The complex interaction between matter and radiation raise many scientific questions. This list of problems could be extended.

These R&D efforts on US are undertaken because there are some advantages of this new separation method which can be seen in table 4.2. The separation factor, a combination of the enrichment factors of the product and the decreasing enrichment factor of the tails, is much better than for the mainly used diffusion or centrifuge technology. The required electrical power per Separative Work Unit referring to a one year production time and the specific costs are also reduced. Nevertheless, one could ask why a new technology must be invented when the worldwide demand for low enriched uranium as reactor fuel is much lower than the existing production capacities (Cf., e.g., Liebert, 1991). The suspicion seems obvious that also military interests are standing behind the partially civilian R&D projects.

In many respects the R&D projects related to LIS are programmes of civil-military ambivalent R&D:

1. LIS plants and even research devices for producing low enriched uranium as reactor fuel could be used for producing weapons-grade highly enriched uranium in significant amounts. This could be done in a two to three stage process only, whereas older techniques need at least ten or up to a thousand times as many more stages.
2. At least the atomic methods could separate the only militarily interesting isotopes of plutonium. The LIS is the first invented method which could manage this difficult task for significant amounts.
3. More nuclear weapon related substances such as tritium, lithium, and transuraniums (americium, californium, curium) could be separated by LIS methods.
4. The scientific understanding of light pressure radiation and the development of sources for laser cooling of atoms, molecules or atomic or molecular beams is interesting for high resolution spectroscopy and for the invention of new time standards. Simultaneously, it is relevant for LIS technique (beam deflection) and probably for solving other problems in other LIS methods by lowering the temperature of atomic or molecular feed stream.
5. Non-linear effects are clearly induced by interactions of lasers and molecules or atoms. This could be used for nonlinear steering of the dissociation process within LIS methods to get a higher efficiency (Ackerhalt, 1984).

LIS techniques would allow for smaller and more efficient facilities which could be hidden successfully within laboratories. In the long run LIS R&D would provide multivalue scientific technological knowledge about many isotope separation tasks with military relevance. For instance, lab scaled LIS facilities can produce significant amounts of enriched uranium. Therefore, it is not enough to prevent the construction of production plants which are planned for the late 1990s in some countries. We have to look at the ongoing R&D. Scientific-technological breakthroughs are always possible and could accelerate the development in direction of a proliferable plutonium separation plant or a small scaled uranium enrichment facility.

Probably one could find differences between several R&D paths. Even more up to now each designed facility or lab scaled process is very specific in details. So, the AVLIS process developed in the 1970s by JNAI (Jersey Nuclear Avco Isotopes) uses rhodamine dye lasers in a three stepped ionization process whereas the LLNL-AVLS process uses copper vapour dye lasers in a two stepped ionization process. In each part of these projects very specific work is brought in and very specific knowledge is produced. These specifications could lead probably to a separation of more or less militarily relevant R&D paths. This should be carefully analyzed.

#### 4.4 Investigating the civilian-military ambivalence of science

Like US, many other fields of science had -and still have- an impact on the military sector. Actually, also the following, surely still incomplete, list of more or less civilian research programmes of big science are very attractive for the military sector.

##### - nuclear energy research

Undoubtedly, nuclear physics provided the possibility for production of fissile materials and the realization of nuclear weapons. The civil-military ambivalence of nuclear and nuclear energy research became evident rather early (Walker, 1990), but it was repressed in countries which desired a massive use of nuclear energy but no nuclear weapons, the latter at least not as an official politically desired task. Today, the civilian waste product of the development of nuclear weapons itself has become the source of militarily motivated nuclear programmes. The risks of nuclear proliferation is mainly energized from the existing ambivalence of nuclear research and technology programmes.

##### - nuclear fusion research

Parts of the nuclear fusion R&D programmes, which are projects of 'big science' in all highly industrialized countries, provide important knowledge for the understanding of nuclear weapons physics and for improvements of nuclear weapons design. Especially the concept of Inertial Confinement Fusion (ICF) is very attractive for military interests. Fusion neutrons, resulting from heavy hydrogen fusion, would be a source for breeding fissile materials.

- *micro-electronics and computer sciences*

The report 'Discriminate Deterrence' states: 'Dramatic developments in military technology appear feasible over the next twenty years' (Discriminate Deterrence 1988: 8). According to this influential report, these revolutions will be driven mainly by "further exploitation of micro-electronics, in particular fOT sensors and information processing." In fact, many programmes fOT the integration of optical and electronic information exist aiming at the development of new sensors, radar systems, electromagnetic or acoustic detectors capable of detecting large objects, propulsion flames or acoustic sources. The ongoing electronic revolution has an impact not only on the creation of new weapon systems but also on the design, the development, the production and the maintenance of armament. Operating new high-tech weapon systems requires adequately sophisticated, reliable computer hardware and software. New computer-architectures can dramatically improve the speed and capability of data processing. Artificial intelligence fOT example has the task to create new unmanned robots and vehicles which can manoeuvre in hostile or complex territory.

- *laser physics*

While the use of laser weaponry fOT blinding, target acquisition and designation or even destruction in the battlefield seems to be unhaltable, continuous improvements of laser power and bandwidth is the aim of civilian R&D without asking fOT the usefulness of these improvements fOT war scenarios. In order to avoid this tendency verifiable limits fOT laser parameters were already suggested (Altmann, 1986). After an authoritative analysis of directed-energy weapons for strategic defense (APS, 1987) there would be demand for a discussion about separation lines between more civilian or more military applicable laser developments. Besides the use of specific types of lasers for LIS or ICF there are other fields of concern.

- *new materials and superconducting research*

New materials like composites, ceramics and crystalline materials can lead to higher energy exploitation and the improvement of gas turbines, engines and rocket systems. New composites are now used in many different weapon platforms for lightweight hulls and ceBs. Important is also the use of radar absorbing materials for stealth aircraft. The exploitation and fabrication of superconducting materials are intended to lead to more compact, higher-efficiency electric drive systems for ships, electric generators and storage systems (also in space), electromagnetic guns and sensors (DOD, 1990).

- *chemistry and genetic research and engineering*

The chemistry of phosphoro-organic combinations and accompanying technologies are usable for production of both plant protectives and chemical weapons. Similarities and distinguishing features of the underlying R&D need to be clarified. Otherwise, the stop of worldwide spreading of chemical weaponry at its source seems to be without prospects. Besides the production of new vaccines or toxic agents within the medical arena the scope of genetic engineering is probably also the field of biological and toxic weapons (Nixdorff, Stumm, 1990).

- *neural network research and nonlinear dynamics*

The actual research on architecture and behaviour of neural networks could on the one hand give explanation for biological mechanisms, e.g., in the brain, while on the other hand it is a basis for the development of new procedures of pattern recognition and for the more and more automatic future battlefield (DARPA, 1988). Finding distinguishing criteria between these two scopes of R&D is of great importance.<sup>32</sup> Not only for the development of LIS the nonlinear dynamics research is of interest. The first bigger research groups were undoubtedly founded within the US Weapons Laboratories. A denomination and demarcation of military research interests is indispensable if this fascinating field of science is not to lose its attractiveness.

In order to analyse these civil-military ambivalent R&D programmes one needs an analytical framework, which provides the basis for understanding the internal scientific development and the finding of measures for halting or more or less avoiding the military use of science.

#### **4.4.1 The analysis of civil-military ambivalent R&D**

The notion of ambivalence was first settled in psychology. This could lead to some considerations about the psychological mechanism of repression within the community of scientists, but this is beyond the scope of this chapter.

A useful definition of ambivalence stems from Carl Friedrich von Weizsäcker (Weizsäcker, 1977: 80). He describes ambivalence as the experience of having to discover that, just as an objective is considered achieved or realized, it appears that the achievement or realization is in fact not identical with the objective but might in fact even prevent it. This fits very well to the problem of civil intended research and its military related outcome. Weizsäcker outlines a model fOT the analysis of ambivalence in distinguishing three 'strata of causality'. The first stratum is the

realm of scientific facts and causalities. This includes also the discussion of the intended main effects of scientific research and technology and unintended side effects. The second stratum deals with the vital social environment, causalities within society in the form of direct action and measures, whereas the third stratum is related to the analysis of the dynamics and statics of societies itself.

Table 4.3 Three layers for the analysis of ambivalence

1. *Internal scientific and technological knowledge*

- \* description and assessment of scientific areas, programmes and projects
- \* their interaction and evolution
- \* inner-scientific interests and legitimations
- \* their long-term civilian/military applications (prospects and possibilities)
- \* tracing of inner-scientific nodal points.

2. *External scientific and social interests and impacts* \* description/assessment of external interests

- \* finding of external scientific/political decision points

3. *Social dynamics and statics/ international framework*

- \* description/assessment of social needs and society related developments
- \* development of cooperative measures, ethics of science, effective arms control procedures.

This gives some very useful hints for the investigation of the civil-military ambivalence of science (cf. table 4.3). In a first step, it might be necessary to make the current process of scientific development more transparent and obvious by establishing additional and accompanying, interdisciplinary research of social and natural scientists of many disciplines. Such attempts could start, for example, in big science projects or universities. Scientific facts, and paths for the development of scientific ideas, have to be worked out. Moreover, the scientific contents, the results, the intentions and applications should be arranged in view of their ambivalence. Their mutual impacts need more understanding and assessment. The point of view should be directed to inner-scientific argumentation and to identification of inner-scientific decision or nodal points which permits to distinguish between different paths of scientific evolution. This could open alternatives for decisionmaking. In this regard, answers to the following questions should be found:

- How essential or unavoidable is a scientific program for the further advancement of basic scientific knowledge?
- Which parts of science are undissolvably interweaved?
- How or how much is basic research and application related research unseparably amalgamated probably by political decision?
- What are the scientific, economic, technological and military aims of research programmes, which are embedded in international connections and cooperations, or the interests behind these aims?

Dealing with these issues in the above order, the causalities of the second stratum, the society related causalities are of increasing importance.

The second step would be the examination of the external interests and the interaction between science and politics. Methods which could clarify the processes of science and technology policy should be elaborated. External decision or nodal points within an appropriate decision-tree has to be identified. One main task would be to trace bifurcation points within this decision-tree based on external and internal nodal points in order to find paths of research and decisions for investment in science and technology from which the military sector cannot or can only hardly benefit.

The third layer corresponds mainly with the tradition of peace research. Here, the task is to analyse the international framework for the conversion of armament dynamics into a dynamical process of disarmament. Besides the development of ideas or the improvement of concepts for arms control procedures, especially for the military-technological innovation process, scientists have to consider problems of ethics and the responsibility of science. Such considerations should bear upon the daily scientific work practically taking serious the humanistic ideals of science.

#### 4.5 Consequences for progress in arms control

As we have pointed out in section 1, traditional arms control deals mainly with parity, crisis management and some geographical restrictions. Arms control efforts of the past have focused more on the East-West confrontation than multilateral arms control including the Third World. Now, we have to pursue a deep reorientation of arms control. As Norway's Minister of Defence J. Holst put in: "Arms control needs to be brought up-to-date with the post cold war area." (Holst, 1991) Under these new political circumstances arms control should not manage the status-quo, but should share the transformation of the international security system without privileging existing minorities of military strength. Therefore the traditional concept of arms control should be extended and new approaches should be discussed and added (see table 4.4).

A set of successful principles can be the basis of a further globalization of arms control. Some measures can clearly

be identified.<sup>33</sup>

*Architectural measures*, that are arrangements such as security ZOLles, nuclearweapon free ZOLles, büffel ZOLles etc., have the purpose to share the political and military geography. As an example a ban of space weapons, only allowing passive surveillance and early warning satellites, could have significant effects on the stabilization of the strategie posture hindering a new uncontrolled arms race in space. Regional commÜments tightening up the Nuclear Non Proliferation Treaty could help to stepwise overcome shortcomings of the non-proliferation regime. *Structural measures* are designed to constrain the size and the composition of forces in regional areas, e.g. the CFE-I Treaty. In this regard, the most stringent approach to restructuring the military forces is proposed by the school of non-offensive defense (NOD).<sup>34</sup> *Operational measures*, such as limiting the size, structure and frequency of peacetime military activities could be correlated with tue above mentioned stroctural measures (e.g., CSBM accord). *Data exchange*, such as publishing or exchanging data on force planning, budget and procurement figures of the past and in the future can enhance predictability thus creating more transparency and confideuce building. *Declaratory measures*, such as a declaration of the no-first-use of nuclear weapons (e.g., NATO is clearly supposed to make such a declaration) or a moratorium on R&D or development can raise the threshold to use military power or can tower the danger of new or 'provident' new weapons invention. *Test bans* could in some cases decourage R&D efforts.

Table 4.4 *Consequences especiaJJy for (qualitative) arms controJ*

Traditional arms control (unilateral, bi-, multilateral)

1. architectural measures {security zones}
2. structural measures (NOO)
3. operational measures (limits)
4. data exchange and verification
5. declaratory measures (defence budgets)
6. test bans.

Global and regional arms control 1. mies on arms sales and exports

2. mies on weapons production
3. mies on testing
4. economic and technologicallylimits

Qualitative, preventive arms control

1. restrictions on military R&O budgets
2. data exchange on military R&O
3. notifying military (related) programmes
4. separation of military and civilian programmes
5. open laboratories, visiting programmes
6. international civilian cooperation
7. R&O conversion programmes
8. adequate verification

Unilateral measures

1. establishing (defence) technology assessment
2. establishing science assessment
3. Opening discussion between scientific community andarms control community (ind ethics of science)
4. education & research progr. in schools & universities

The highlights of 1991, the second GulfWar and the unsuccessful *coup d'etat* in the Soviet Union illuminate the prospects and challenges of future arms control. In the past, Iraq was supported by Western and Eastern arms transfers, military assistance and high-technology. Tbis buge arsenal, partially accumulated before the Iran-Iraq war, was reduced by brote force during the recent war. Due to the disintegration of the Soviet Union, several nuclear equipped republics face the problem of the security of existing nuclear weapons. A tightening of *rules on exports and testing* with the aim of an end to weapons export and new weapons testing should be Olle consequence, hut also the eonomie limits of weapons production are apparent and should lead to *rules on weapons production* and commitments on *technological limits*.

The renner chief of the US START delegation, Richard Burt, proposed to make the technological innovation process itself the subject of innovation. There are proposals and even first practical steps to leave the traditional approach of quantitative anns control and to implement more qualitative measures, e.g., the discussion and *notificationofthe* military doctrines, of procurement and *R&D programmes*, agreed restrictions on *military R&D budgets*. Provided that there is the political will as well as the emergence of scientists' conscience then additional measures would be possible. *Laboratories* of concern could be *opened for visits* and discussions, *R&D conversion plans* could be worked out by joint task force groups of scientists and politicians. A new *intemational civilian scientific cooperation* (taking the IAEA *not* as a model<sup>35</sup>) could be envisioned with existing scientific capabilities. Even the problem of verification of research facilities could be tackled. It would not be easy to handle (cf. Smit, 1990), hut joint programmes in sensitive fields of research could be a first measure.

In the times of global d' etente *unilateral measures* might be a retter way to achieve anus control and disannament. Such measures might be quicker and more effective than with lang during negotiations.

Agreements on a moratorium or even a ban of some projects of militarily relevant R&D (e.g., für achieving performance of specific characteristics für instance of used laser systems) could be a way für halting the scientific-technological and innovation process. More appropriate would be the steering of the related R&D process by funding decisions.<sup>36</sup> For instance, only well funded LIS projects, lasting für years, bringing together a lot of scientists and engineers have a chance to achieve technological maturity. The reduction of the flow of money into military relevant R&D projects and the diversion into civilian desired R&D could serve the aim of peace more than the discussion about partial bans of R&D. The base für rational funding decisions has to be elaborated by technology assessment and especially by *science assessment*.<sup>37</sup>

At the same time, the fatalistic attitude of scientists faced with the accelerating dynamics of scientific knowledge which has destructive impacts has to overcome by:

- a debate about the latent and intended use of science für military purposes;
- the strengthening of the sensitivity of scientists für the need to assess the consequences of their work not only in same few interdisciplinary research groups but also in their daily work;
- a change of the consciousness by the scientists to work only für life but not für death.

In sum, the analysis of the civil-military ambivalence of R&D projects has the goal to minimize the military use of science and to strengthen the civilian use of science für purposes of peace and just development of mankind. In this regard, the approach of a more effective technology assessment is clearly not enough, if the scientific driven qualitative and race should be halted. It is necessary to establish a kind of science assessment with the aim to detect, describe and reduce the use of science für militarily relevant purposes.

## Notes

1. For a precise description of mechanisms within the nuclear arms race, see Holdren (1983).
2. Statement of Secretary of Defence R. Cheney für Fiscal Year 1992-1993, 21.2.1991, p.19.
3. See für the case of inertial confinement fusion Schaper (1989).
4. Source as in footnote 2.
5. Cf. Böhme (1983).
6. Besides Zuckerman, see also Bamaby (1981), Thee (1990).
7. For a short overview, cf. Liebert and Neuneck (1991).
8. B. Bowie, quoted in Sheehan (1988: 6).
9. Cf. also Goldblat (1982).
10. See, für example: Antarctica Treaty 1959, Art. I; Outer Space Treaty 1967, Art. IV; Treaty of Tlatelolco 1967, Art. I; Seabed Treaty 1971, Art. I; Threshold Test Ban Treaty 1974, Art. I; INF-Treaty, Art. IV.
11. See, e.g., BWC 1972, Art. I; the AHM Treaty 1972, Art. v; SALTII 1979, Art. I.
12. See also by E. Geissler in this volume.
13. Cf. Deutscher Bundestag (1990: 19/20).
14. E.g., IABG (1985), Kubbig (1986), Albrecht (1989).
15. Source: Deutscher Bundestag (1990: 29,38)
16. Original: 'Der BMVg baut mit seinen Vorhaben zu F\IT grundsätzlich auf ziviler Forschung und Technologie auf. Nur soweit unabweisbar wird die zivile wissenschaftlich-technische Basis durch eigene Vorhaben ergänzt.' (Deutscher Bundestag, 1990: 21)
17. Cf. Liebert et al. (1988). The notion of ambivalence of science is a more appropriate designation than dual-use because the latter makes more sense in the field of technological outputs.
18.  $^{235}\text{U}$  is the fissionable isotope of uranium; natural uranium contains only 0.7%  $^{235}\text{U}$ . The enrichment of uranium is needed for the production of reactor fuel as well as for the manufacturing of workable nuclear weapons.
19. Mainly based on Krass et al. (1983) and Plurien (1989)
20. This specification makes not so much sense für calutron, but für comparison with the other technologies it is based on the assumption that the enrichment factor is about 20, and only one part of ten of the uranium feed stream is separable.
21. 0.5 W takes into account the power needed for the photon production, whereas 7.0 W is due to the needed electric power required for the heating of the e.g. uranium metal with an electron gun in case of atomic methods.
22. For the discussion of laser isotope separation especially its proliferation risks compare, also the contribution of Schaper et al. in this volume.

23. Cf., e.g., Ertmer (1987).
24. Cf., e.g., Forsen (1980).
25. Cf. Krass et al (1983).
26. Cf. also the contribution of Schaper et al. in this volume, especially table 2.
27. For the military relevance of tritium, cf. Kalinowski (1989).
28. Cf. Ashkin (1987).
29. Cf. Bemhardt et al. (1976).
30. Cf., e.g., Liebert (1991).
31. Cf. Schaper et al. in this book.
32. Material for the beginning discussion is given in Jathe, Scheffran (1991).
33. For the notions, see Holst (1991).
34. Cf. Weizsäcker (1990).
35. Other fields of cooperation as just the civil-military ambivalent nuclear science and technology, should be chosen, unless Olle would tackle the urgent problem of nuclear waste. Furthermore, it is not a good idea to entrust an organisation with the coordination which has the double task of international promoting and controlling a field of technology.
36. The theoretical base for such a possibility without restricting the "freedom of scientific work" has been elaborated in the late 1970s (Böhme et al, 1978) The main point is that modern scientific research in many cases is not basic research but 'postparadigmatic' in the sense that it is based on more or less mature or closed theories. Within this final stage of science further theoretical development is more oriented to the solution of problems stemming from society than from inner scientific development. 'Finalization' of science describes the fact that there "is a process through which external goals for science become the guideline of the development of scientific theory itself."
37. For the concept of Defence Technology Assessment, see Ter Borg and Smit (1989), and for the need of science assessment, see Liebert and Neuneck (1991).